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# A Study On Rock Information Enhancement Of Remote Sensing Image By Multi-Fractal Filter Method

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***Abstract***

*A remote sensing image is composed of vegetation and base rock or soil in moutain areas, which can be decomposed by the fractal model through Fourier transformation to enhance base rock or soil information. In this paper, four scene images of two types of bed rock from Anhui province are taken as a case to demonstrate the method's validity: two scene images' base rocks are monzonite granite while the other two base rock are limestone and mudstone. The fractal spectrum of the four scene images can't be distinguished without processing yet the result shows good contrast for the two types of rock. Other contrasts between original and processed images show obvious difference in the two types of image such as in 2D-scatter map, in composed color map. The result proves that the method can improve base rock information in those vegetation covering region.*

***Keywords****: multi-fractal; fractal filter; remote sensing image; rock enhancement*

## 1. Introduction

The geological information extraction from vegetation covering region is the focus of remote sensing geology[1,2],and the geology information includes rock distribution, mineralization and structure information[9].The current study for geological information extraction is mainly classfied into texture based way and spectrum based way, or the two combined way, such as taking image texture values as a spectrum band[4,6], taking spectrum fracture value as a band to classification process[7], the above ways can improve the accuracy of classification or rock recognition[2].Some researchers employ rough set and concept lattice model to mine the relationship between base rock and vegetation for qualitative analysis[8].The methods above achieve some goals in those rare vegetation regions [2].The spectrum based way is dependent on the remote sensing image spectrum resolution, while the texture based way can find more information at the same spectrum resolution.

The multi-fracture is getting more and more attention in the images' character extraction and pattern recognition recently [5], which is invented to describle irregular shapes firstly by Mandelbrot B B. and widely applied in broad fields later. Multi-fracture means more than one fracture twisted in space, providing a method to detect the multi-interwined relation in a system and describe their characteristics by fractal spectrum. Remote sensing image with similar bedrock owns the similar texture characteristic, which can be modeled by multi-fracture through the spatial texture self similarity and scale invarianc.

Currently, fracture method is mainly used for texture information expression and extraction in remote sensing geology filed. The texture of remote sensing image mainly reflects the roughness of ground, which is a complex system made up by various ground reflectivity. The roughness of ground is determined by geology bodies and landscapes, because the properties of ground rock and soil are in favor of different weathering,

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erosion, accumulation and vegetation distribution, especially the ground fine drainage network, leading to the diversity of ground roughness. Yet the images with similar lithology show the similar reflectivity combination in space for the similar landscapes, which can be modeled through the pixels value repeatition structure by mathematics, but the geology bodies vary seriously in 3-d dimension.The repetition structure is far from the general repetition, because firstly the repetition is mostly anisotropic, such as images of banding folds region, without repetition characteristics along strike possibly.Secondly, the repetition of texture is not simple periodical repetition as weaving. It is concluded that the texture of geology bodies is not only repeated statistically but also non-reproductive in shapes anywhere. Fractal dimension can be calculated in a suitable neighbour window for each pixel one by one, which is adopted as an additive band to improve the classification efficiency, but the vegetation component is still reserved. Cheng[14] proves the generalized self-similarity existing in "gene map" such as Fourier spectrum;eigenvector spectrum of original image, the mixing or superposed system can be decomposed into background and abnormity by principle of generalization self-similarity[14].

This paper tries to employ multi-fracture filter way to enhance the base rock or soil information based on the texture compositions optic mechanism, and examine the effect by images with known bedrock, to seek an effective way to enhance base rock information by low spectrum resolution ETM images.

## 2. The Decomposition of Components at Frequency Domain

ChristopherSmall's research through the spectrum mixing space of global 30 scenes classic ETM+ images indicates that the spectrum of any image is mixed by soil, rock or strata, vegetation and back material[11]. This suggestion shows us that the reflectivity of any band can be composed by these four types materials [12]. But for geological information, the soil and rock can be considered as combined base information;the vegetation is the main covering factor, and black material is made up of water bodies and shadow. The reflectivity image of any band $f(x,y)$ can be taken as the sum of different component reflectivity:

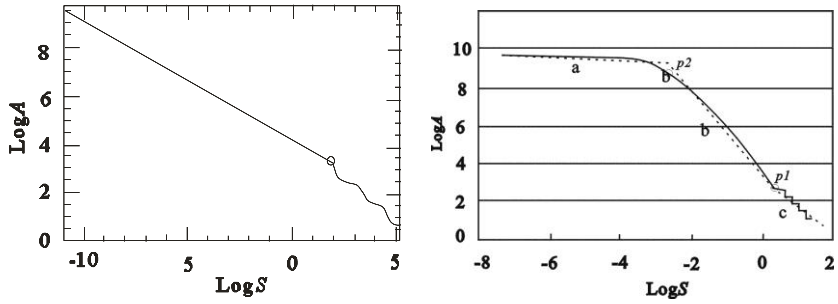
$$f(x,y)=\sum_{i=0}^{n}s_i(x,y) \tag{1}$$

Yet it is difficult to separate the reflectivity in the spatial domain because the pixel value of reflectivity is mixed by vegetation and base rock or soil. But the reflectivity changing of vegetation is continuous in the frequency domain, which can be represented by low frequency component $S_h(u,v)$; the strata, rock reflectivity changing is jumping and discontinuous and can be represented by high frequency $S_l(u,v)$. A suitable threshold can be helpful to separate the base and vegetation frequency. By employing flourier transform, an image can be transformed into an energy density image $S(u,v)$, the energy of different frequency obeys fractal distribution[13].The fractal filter technology（$S-A$） invented by Cheng（2006）[14] is employed here：

$$A(>S_0)\propto S^{-\beta} \tag{2}$$

$A$ is the area(number of pixels) of energy density bigger than a critical value $(S_0)$ at frequency domain, $\beta$ is the index of fractal model. Different $\beta$ value can be calculated on the map of $\log A(>S_0)-\log(S_0)$;the zone of different $S_0$ responds to different linear relationship,different linear relationship responds to multi-fracture. The high energy linear part is related to low frequency while the low energy linear part means high frequency part (Figure 1).




a b

**Figure 1. Log-Log Plot of Energy and Responding Area (A is Theoretic Map and B Is a Real One)**

The intersection point of two straight lines can be used to determine the threshold for fractal filter. Some frequency filter can be constructed by the threshold to achieve the goal of separating the base and vegetation after transforming the filtered image back into spatial domain.

Three lines a, b, c existing in Figureure1b indicate that there are three parts power relationship of $S-A$ existing:line a is flat meaning the low energy and high frequency part, line b is the middle part energy distribution and middle frequency, line c is the high energy part and low frequency distribution. In a remote sensing image, the low frequency part usually comes from even ground materials such as a lake, a thick plant area; the middle and high part mainly reflects the pixels seriously changing area including the rock, soil exposed below vegetation alternatively. The anbnormity of geology bodies is often related to the high frequency while the background of thick vegetation and water bodies is associated with low frequency; the intersection point *p1* provides the suitable threshold for weakening the thick vegetation by keeping $S < p1$ part and transforming it back to spatial domain.

## 3. The Description of Research Area and Data

### 3.1. Overview of Geography and Geology of Research Area

The research area is located around Huainan city, Anhui province, China, in which the bedrock exposed area takes the form of strip hill. The area is the north margin of collision arc basin by south China plate and north China plate. The stratum distribution is developed from the Archean to the Cenozoic except in Silurian and Devonian, and the magmatic rock distributes widely for the Tanlu fault. The vegetation coverage is high to middle,sporadic appearance of strata and soil can be found.The topographic differences of the four scene images are similar.

### 3.2. The Data Source and Pre-processing

The research ETM images are received in 2012 for Anhui province, and the images are mosaicked and geography corrected.Four scene images of 1024 pixels ×1024 pixels are clipped from the full image according to the geological map of 1:500000 scale;Two scene images are located at mantou-maozhuang formation of lower Cambrian with the rock character as pale yellow sandstone and gray oolitic limestone interbedded. The main thickness is made up of limestone, the other two image's base rock are Metamorphic granite gneiss.

An ETM image includes 8 bands, this paper processed band1-5, and band7 by the method above. Listed below is the original false color composed image of the four scenes:

a b c d

a.mantou-maozhuang formation of Shangyao b.mantou-maozhuang formation of Jiushandong

c. granitic gneiss of Bengbu d. granitic gneiss of Dabie mountain

**Figure 2. Four Images From Two Types of Base Rock (Composed by Band 321,Cutoff at 2% Grey）**

It is difficult to distinguish the left two images underlying the same rock from the right two also owning the same rock by the original images.

## 4. The Result Analysis and Discussions

Firstly, band 7 of the four images is rocessed by the method in part 2, because the band 7 of ETM shows rock or soil information prominently and slightly influenced by vegetation[12].The left six bands of Bengbu scene are also processed to carry out the comparision of spectral space structure.

Multi-fractal spectrum is applied to quantitatively analyse the contrastbetween original and processed images according to their underlying bedrock type. For the remote sensing image with bedrock, the law of texture changing in partial space obeys some spatial principle and it can be described by singularity spectrum, and the law is the same to the combination relations of vegetation and rocks [2].

### 4.1. Analysis of Fractal Spectrum Between Original and Processed Images

Projection cover method by Xie[16] is employed for probability measure of multi-fractal spectrum. The fractal relationship is determined as:

$$A(\delta) = \sum_{k=1}^{N(\delta)} A_k(\delta) \propto \delta^{2-D} \qquad (3)$$

$A$ is the total area of an image at different measurements; δ is the length of measurement. This study takes 8×8 , 16×16 , 32×32 , 64×64 , 128×128 , 256×256(pixels steps) as six measurement. $D$ is the fractal dimension. The area $A$ of each square at different measurement can be calculated by the formula:

$$A_k(\delta \times \delta) = A_k(\delta) = \frac{1}{2}\{[\delta^2 + (h_{ak} - h_{dk})^2] + \left[\delta^2 + (h_{dk} - h_{ck})^2\right] + \left[\delta^2 + (h_{ak} - h_{bk})^2\right]\left[\delta^2 + (h_{bk} - h_{ck})^2\right]\} \qquad (4)$$

$h_{ak}, h_{bk}, h_{ck}, h_{dk}$ are the four pixels value and they can be looked as height to calculate the surface area of each square(Figure3), the next steps to get fractal singularity spectrum are introduced in many literatures[17] with unnecessary details here.

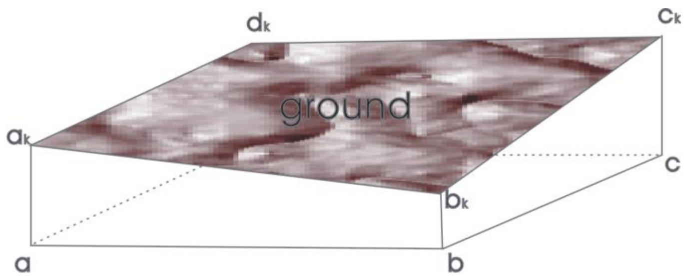



**Figure 3. Sketch Showing Measurement of the Earth's Surface by using the Projective Covering Method（Modified From[18]）**

The multi-fractal spectrum maps of band7 from four sub images are contrasted in Figure4, the left two are the original maps and the right two are the processed maps. In the $f(a)-a$ spectrum map(up), the range of singularity value $a$ of processed image becomes wider than original image, implying the self-similar law becoming strong after fractal filter, and the max a values of right map are bigger than the left map indicating the spatial texture changing smoothly. For the full shape, the left spectrums are left side fractal, meaning the high frequency that is mixed pixels by vegetation and rock is abundant but after processing, the symmetrical shape shows base rock becomes strong.

A more interesting result is that the spectrum curves become consistent according to their base rock type at the low Hoddle index( $a$ ) part in right map, but their original left curves show no relationship to base rock. The result also tells that the filtered image owns the similar curves according to their bedrock types, implying the fractal filter model enhanced the underlying base rock information. Another result from the map is that the Hoddle index( $a$ ) of mantou-maozhuang formation underlying image is bigger than granite underlying image, indicating the singularity of granite underlying image is smaller than maotou-maozhuang underlying image, showing a fact that the vegetation uniformity of graniteunderlying image is better than the limestone-mud-sandstone area. The images cannot be distinguished according to their base underlying rock at the high Hoddle index ( $a$ ) part, because this part represents the low frequency of vegetation strongly covered pixels.

In the $D(q)-q$ spectrum map, the original images' curves cannot be distinguished at the $q$ <<0 part, but the $D(q)$ value of granite underlying images becomes smaller at the $q$ >>1 part. After being filtered, the $D(q)$ of limestone-mud-sandstone based images become bigger and consistent. This $D(q)-q$ spectrum shows two information: one is that the $\Delta D$ of filtered images become wide, indicating the less uniformity image becomes strong; another is that the image with different bedrock can be recognized by the generalized fractal dimension( $D(q)$ ) after being filtered, and the $D(q)$ of granite underlying images are smaller than limestone-mud-sandstone underlying images indicating the same geological meaning as $f(a)-a$ spectrum.

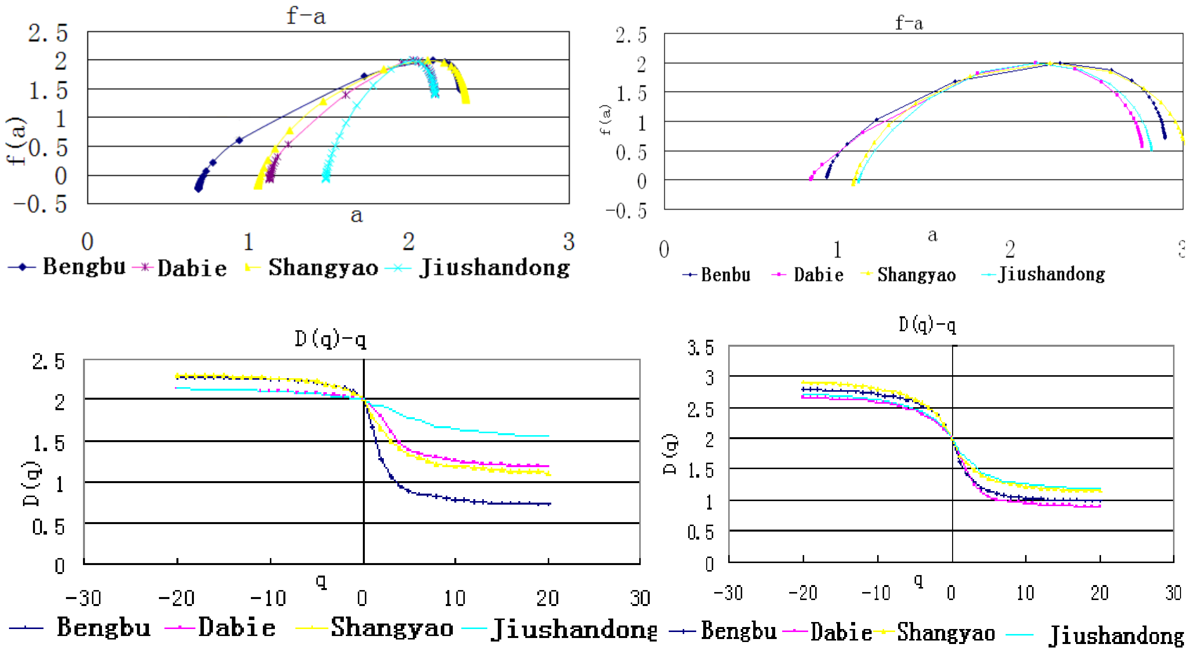



**Figure 4. The Multi-Fractal Spectrum of Four Images (Left for Original, Right for Processed）**

### 4.2. Spectrum Spatial Structure Analysis

ChristopherSmal's work shows a result that the 98% spectrum information of remote sensing images can be described in 3D-scatter, and at least 90% spectrum information can be represented at 2D-scatter, and his suggestion helps us to analyze the information change through this spectrum scatter [12].

In Figure5, the 2D-scatter map of band 3(axis x) and band 4(axis y) for original Bengbu image(Figure5a) is contrasted to the same 2D-scatter map for filtered Bengbu image(Figure5b). The discrete points of later shows that the processed image is easily decomposed into more information. Figure5c is 2D-scatter map of original band3(axis x) and itself(axis y) shows a straight line of course, but the 2D-scatter map of band3(axis x, from original image) and band3(axis y, from filtered image) shows new information appears at the left lower part which is proven as vegetation covering rock area.

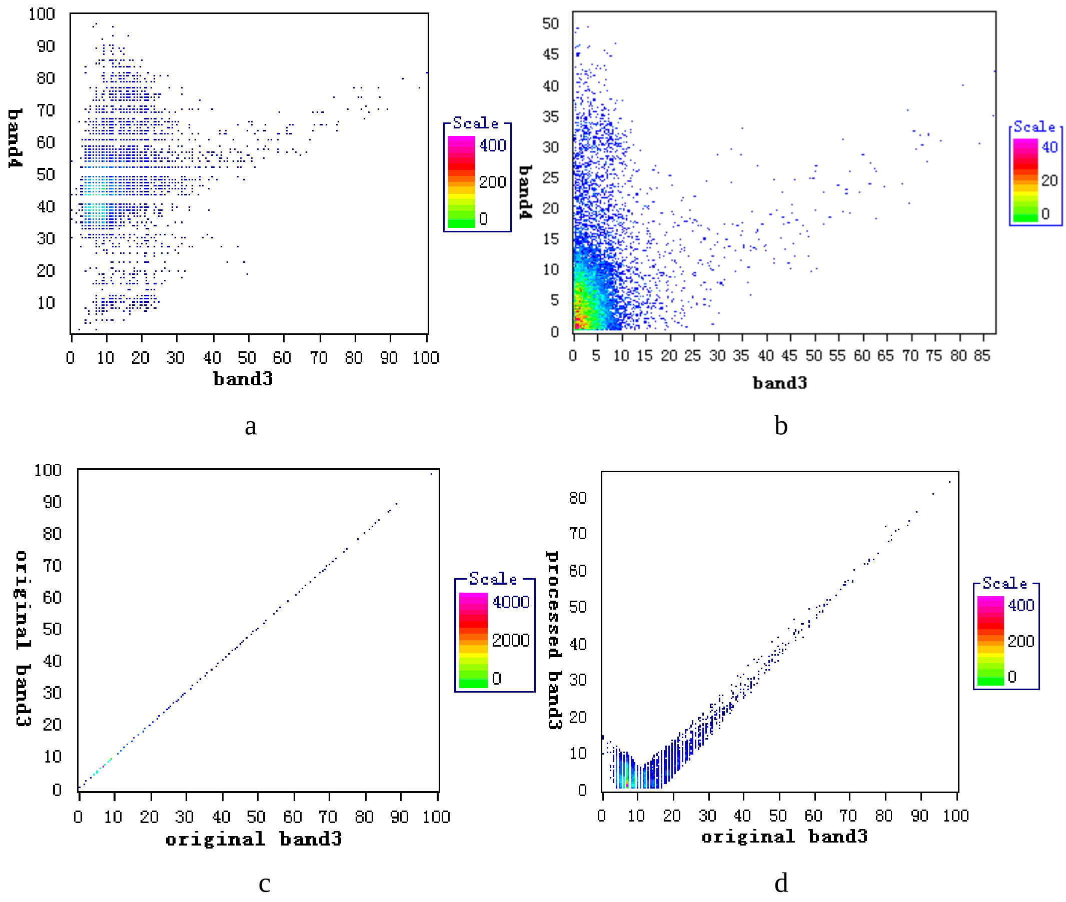



**Figure 5. The 2D-Scatter Maps of Bengbu Image (Introduced In Part 4.2)**

### 4.3. Visual Contrast

The Figure6 shows the false color composed image of Bengbu granite based image by band 3,2,1, the left one is an original image, the right is the filtered image. The right shows a suitable distribution of underlying rock, for example, the rock is distributed at the top of mountain and cliffs neighboring the lakes more than valleys in this area. The right image shows this law more obviously than the left one. The processed image at right tells the fact that the vegetation is distributed densely along river sides. Another point is that the upper left area is farmland in fact which shows suitable texture than original image on the left.

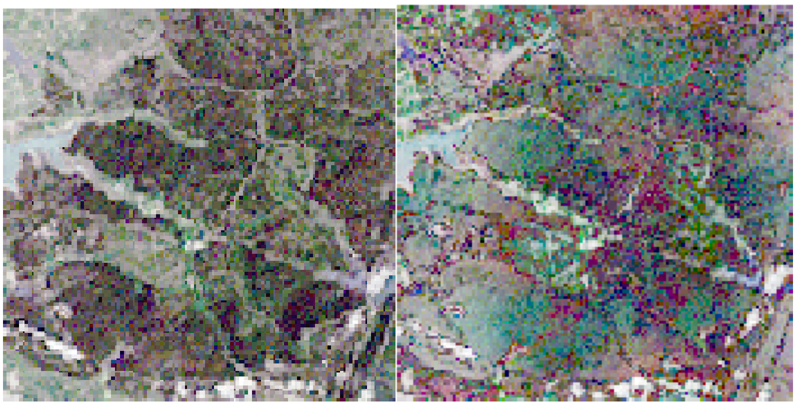
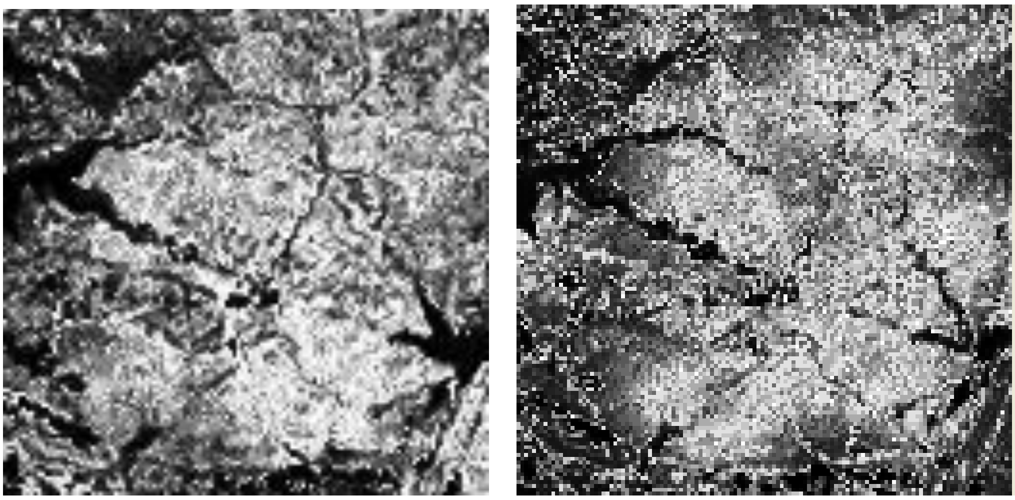


**Figure 6. The False Color Composed Image of Bengbu Granite by Band3 (R)2 (G)1 (B) Left Is Original Image, Right Is Processed Image）**

### 4.4. NDVI Image Contrast

NDVI is the abbreviated form for Normalized Difference Vegetation Index which is used to detect the vegetation growth and covering state.An ndvi image is produced by formula $(NIR-R)/(NIR+R)$ when there are near-infrared band and red band available.

Figure7 illustrates the contrast between NDVI map of original TM image(a) and S/A processed image(b), the vegetation coverage density decreases collectively, the bed rock becomes continuous and whole on the processed NDVI image. The high(white pixels) part of NDVI still remains as the original NDVI image but only the thin(gray pixels) part reduces at the reasonable area such as the centre image. Notice that a “heart shape” geology body appears on the centre of right image. Another point is that the vegetation becomes thicker along the streams on the image reasonably.



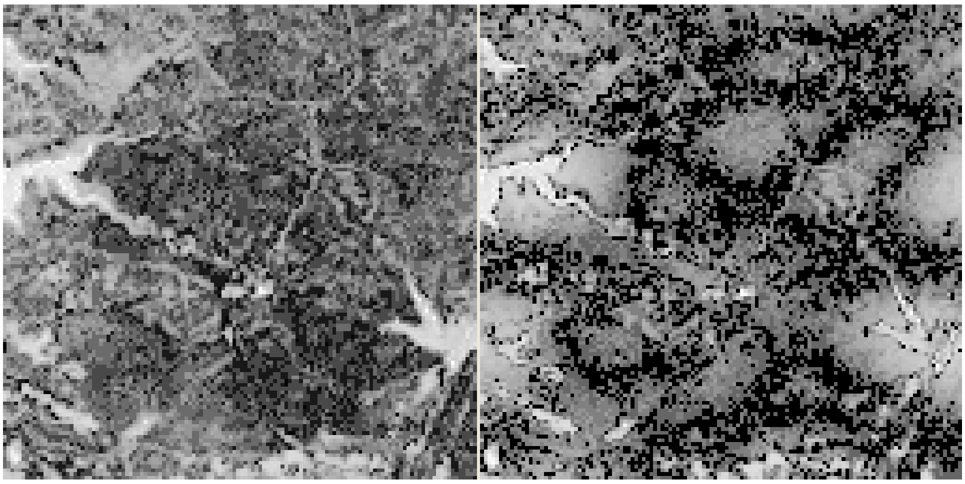
a b

**Figure 7. The NDVI Map Of Original And S/A Processed Image**

### 4.5. B3/B4 Characters Comparison

A band math of ration ETM3/ETM4 is used to reduce the vegetation[19], which is widely applied in minerals alteration information extraction. Figure8 contrasts the original result(a) with the processed result(b) with obvious highlight bedrock distribution, and some buried structure is clearly revealed in the right image.

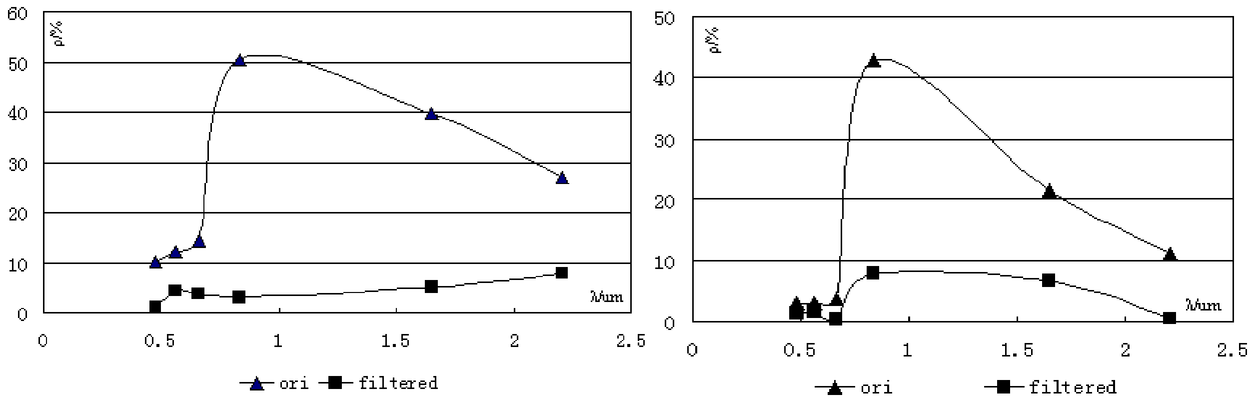


a b

**Figure 8. A Ration Image of ETM3/ETM4 to Reduce Vegetation (A Is Original Result, B ss Processed Result)**

### 4.6. The Spectrum Curve Change

Some spectrum curves of pixels at different vegetation covering area are extracted from multi-spectrum image to check the changing law(Figure9).The left map(a) is the spectrum curves from thin vegetation area,the curve with triangle is original curve showing strong characters of green plants because the reflectivity at near-infrared becomes high abruptly, but the curve with square from processed multi-spectrm image shows more characters similar to rock's. The right map reveals the same law of curves changie but the vegetation characters are clearer than the left one. The Figure9 implies that the processed image has enhanced the bed rock information in some degree.




a b

**Figure 9. The Spectrum Curve Changing of Thin Vegetation (A) and Thick Vegetation (B) Area**

## 5. Conclusions and Acknowledgements

Two types of ETM images underlying different bedrock are processed by fractal-filter model to enhance the base rock information, the result is assessed by fractal singularity spectrum map, by spectrum 2D-scatter map, by visual contrast. Four suggestions are offered here after the study.

(1)The multi-fractal spectrum maps of original images do not correspond to the base rock.

(2) The multi-fractal spectrum maps underlying the same rock become consistent after fractal-filter processing and the consistent part lies in high frequency indicating the underlying rock information enhanced. A part of new information exists on the 2D-scatter map created by original band 3 as x axis and filtered band3 as y axis.

(3)This fractal-filter model is helpful for separating underlying rock component, providing a new way to distinguish the ETM images with different base rock on the multi-fractal singularity spectrum map. The visual contrast becomes suitable by false color composed way after the process.

(4)The comparision of NDVI,B3/B4 and spectrum curves change imply that the multi-spectrm image reveals more bedrock information and the images underlying the same bedrock can be distinguished after S/A processing.

Although the four images with two types of base rock can be distinguished by the model introduced in part 2,the results are mainly qualitative,and the quantitative relationship between rock type and $f(a)-a$ map deserves further study.

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## References

[1] W. Pan, G. Ni and H. Li, "A study of RS image landform frame and lithologic component decomposing algorithm and multi-fractal feature of rock types", Earth Science Frontiers, vol. 16, no. 6 , **(2009)**, pp. 248- 256.
[2] Y. Mo and X. Xi, "Carbonate Rock Lithological Discrimination by Remote Sensing Data for Areas with Flourish Vegetation", Journal of Guilin University of Technology, vol. 30, no. 1, **(2010)**, pp.41-46
[3] A. Wang , S. Liu, A. Wang, D. Cao, L. Li, J. Xia and Y. Qu, "A study of the litho-logical identification based on Hyperion and field spectra", Geological Bulletin of China, vol30. no. 5, **(2011)**, pp.773-782.
[4] C. Xue and X. Wang, "Methodology and application of remotesensing image texture analysis based on fractal geometry", Geological Science and Technology Information, vol. 16-sup, **(1997)**, pp.99-105.
[5] P. Li, K. Hu and Bh. Zhang, "Design and application about computer program of material multif ractal spectrum",Journal of Nanjing University of Aeronautics and Astronautics, vol. 26, no. 1, **(2004)**, pp.78-81.
[6] H. Zhao, H. Cai and N. Li, "Feature extraction method based on multi-fractal parameters for hyper-spectral imagery", Journal of Beijing University of Aeronautics and Astronautics, vol. 38, no. 10, **(2012)**, pp.1317-1320.
[7] H. Du, W. Jin, H. Ge, W. Fan and X. Xu, "Using Fractal Dimensions of Hyperspectral Curves to Analyze the Healthy Status of Vegetation", Spectroscopy and Spectral Analysi, vol. 29, no. 8, **(2009)**, pp.2136-2319.,
[8] X. Wang and R. Niu, "Distribution Rule Mining of Lithology in Three Gorges,Computer science", vol. 36, no. 6, **(2009)**, pp.245-247.
[9] R. Wang, S. Xiong and H. Nie, "Remote Sensing Technology and its Application in Geological Exploration", Acta Geological Sinica, vol. 85, no. 11, **(2011)**, pp.1699-1743.
[10] X. Zhu, "Extracting Geological Structure Information by Multi-Principal Component Analysis", Journal of Remote Sensing, vol.4, no. 4, **(2000)**, pp. 299-303.
[11] K.R. Castleman and Z. Zhu, "Digital Image Processing", Beijing: Electronic Industry Press, **(2003)**.
[12] Y. Zhang, D. Wu, G. Zhu and Z. Yang, "The Problems of Background and Interreference in Remote Sensing Alteration Information on Detection", Remote Sensing for Land＆Resources, vol. 2, no. 76, **(2008)**, pp.22-26.
[13] Z. Chen and K. G. Osadetz, "Undiscovered Petroleum Accumulation Mapping Using Model-Based Stochastic Simulation", Mathematical Geology, vol. 38, no. 1, **(2006)**, pp. 1-15.
[14] Q. Cheng, "Singularity-Generalized Self-Similarity-Fractal Spectrum (3S) Models", Earth

 

Science-Journal of China University of Geo sciences, vol. 31, no. 3, **(2006)**, pp.337-348.
[15] L. Lai ,J. Fang, L. Yu , H. Zhang, "Improving the Quality of Optical Remote Sensing Images Based on Multi-fractal Technique", Bulletin of Surveying and mapping, vol.12, **(2010)**, pp.49-50.
[16] H. Xie and J. Wang, "Multi-fractal Behaviors of Fracture Surfaces in Rocks", Journal of Disaster Prevention and Mitigation Engineering, vol. 30, no. 3, **(1998)**, pp.314-320.
[17] S. Xie, Q. Cheng, L. Qiuming, X. Xing and S. Chen, "Assessing Micro structures of Ore-Minerals by Multi-fractal", Earth Science-Journal of China University of Geosciences, vol. 34, no. 2, **(2009)**, pp. 263-269.
[18] Y. Xie, K. Tan and G. Chen, "Fractal Measure of The Earth's Surface and Geotectonics, Geotectonica et Metallogenia", vol. 28, no. 1, **(2004)**, pp.74-80.
[19] J. Cheng, H. Guo and W. Shi, "The uncertainty problem of remote sensing data", Beijing, Science press, **(2004)**, pp. 30-113.