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SOME KEY ISSUES ON THE APPLICATION OF SATELLITE REMOTE SENSING TO MINING AREAS

DU Pei-jun[1, 2], ZHOU Xing-dong[3], GUO Da-zhi[1]
(1. China University of Mining & Technology, Xuzhou 221008, P. R. China; 2. Shanghai Jiaotong University, Shanghai 200030 P. R. China; 3. Xuzhou Normal University, Xuzhou 221011, P. R. China)

ABSTRACT: In order to apply Satellite Remote Sensing (RS) to mining areas, some key issues should be solved. Based on an introduction to relative studying background, related key issues are proposed and analyzed oriented to the development of RS information science and demands of mining areas. Band selection and combination optimization of Landsat TM is discussed firstly, and it proved that the combination of Band 3, Band 4 and Band 5 has the largest information amount in all three-band combination schemes by both N-dimensional entropy method and Genetic Algorithm (GA). After that the filtering of Radarsat image is discussed. Different filtering methods are experimented and compared, and adaptive methods are more efficient than others. Finally the classification of satellite RS image is studied, and some new methods including classification by improved BPNN(Back Propagation Neural Network) and classification based on GIS and knowledge are proposed.

KEY WORDS: Satellite Remote Sensing; mining areas; band combination; filtering; image classification

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1 INTRODUCTION

Satellite Remote Sensing (RS) has got rapid progress since the 1980s, characterized by the accumulation of multi-temporal, multi-resolution, multi-platform and multi-spectral RS information and the wide and deep application of RS technology. The RS spatial, temporal and spectral resolution all got great improvement, and high-resolution satellite RS with 1m resolution has already been used. Different areas and cities have applied satellite RS to their construction and development and got great benefit, especially for the issues such as resources, environment, land use and urban growth monitoring. But the application of satellite RS to mining areas, a kind of special geographical region with serious environmental and resource problems, laid behind the development of RS application to a great extent, so this topic should be paid more attention to the sustainable development of mining areas.

Mining areas, taking resource exploiting, processing and utilizing as their borehole industry, are formed near the main coalfields and mines and have developed for decades of years, even more. There are many problems such as serious environmental pollution, heavy social and economic burden, sharp contradictions and laggard productivity and infrastructure construction in mining cities.

In order to solve those problems, it is important to protect the limited mineral resources, polluted environment and damaged ecological system, and RS will play important roles in this process.

In this paper, we focus on some key issues on applying satellite RS to mining area. By analysis and comparison, two types of most popular RS information sources, Landsat TM launched by USA and Radarsat launched by Canada are selected as the data sources, and Xuzhou mining area in Jiangsu Province is taken as the study area.

2 KEY ISSUES ON THE APPLICATIONS OF SATELLITE RS TO MINING AREAS

According to our studies, the key issues on applying satellite RS to mining areas mainly include:

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Biography: DU Pei-jun(1975 -), male, a native of Wutai County, Shaanxi Province, Ph. D., associate professor, specialized in theories and application of RS, GIS and their integration.

(1) The RS information mechanism and pattern of the typical phenomena and procedure in mining areas. There are many special and characteristic phenomena that are accompanied by land surface changing in mining areas. If their RS information mechanism and pattern can be established, we will be able to apply RS to extract useful information.

(2) Effective information source selection and combination. There are many RS information sources available at present, and different information has its properties and characterized by different cost, adaptability, advantages and shortages. So effective information source selection and combination are vital to the application performance.

(3) Effective classification methods. Artificial Neural Network (ANN) has been used to RS classification in recent years and got better results than traditional methods, and it will promote the automatic and intelligent interpretation of RS images. In addition, more features are used in classification, such as texture, shape and spectral feature, and also domain expert knowledge is introduced to form Expert System to RS image classification.

(4) Reliable thematic information extraction models. The key of RS thematic analysis is to extract useful thematic information from RS images. This work should be done based on the RS mechanism and features. Every ground object and land cover has its own spectral, spatial and texture features in different RS information sources. Based on some sampling areas, the knowledge and rules can be established and then corresponding models can be used to extract thematic information.

(5) Feature extraction and knowledge discovery. In order to realize the automatic and intelligent interpretation and processing of RS images, effective feature extraction and knowledge discovery algorithms should be proposed. In this sense, Artificial Intelligence (AI), ANN, Genetic Algorithm (GA), Rough Set (RS), wavelet, fractal and other branches of computation intelligence and nonlinear science should be introduced.

(6) The integration of RS with GIS, GPS(LI and GUAN, 2000).

3 BAND SELECTION AND COMBINATION OF LANDSAT TM

There are correlativity, information redundancy and mutual complementarity in different bands of TM image. The practical effect is determined by band selection and combination to a great extent, and that is to select an optimized sub-set from all bands essentially. It is not the best solution to use more bands in the six bands (except Band 6) and their different combinations because of their information correlativity, complexity, more time-consuming and higher demands to software and hardware of multi-band processing. So it is necessary to select the most effective bands for specific task. Among all selection schemes, the selection method based on N-dimensional entropy has the advantages of whole considering factors, easy operation, obvious effect and others, and its algorithm can be expressed by (DAI and LEI, 1989; FANG and HUANG, 1997):

$$S = \sum_{i=1}^{M} P_i(x)\ln P_i(x) \qquad (1)$$

where S is the entropy value, M is the total amount of pixels in sampling area, $P_i(x)$ is the probability density function of variant and it can be viewed as fomula (2) in normal distribution:

$$P_i(x) = 1/K_s\exp[-(x-\bar{x})^T M_s^{-1}(x-\bar{x})/2] \qquad (2)$$

where $K_s = (2\pi)^{\frac{N}{2}} M_s^{\frac{1}{2}}$, M_s is the covariance matrix of sampling area, x is image variant or gray value, $\bar{x}$ is mean of image or mean gray.

RS image can be viewed as normal distribution approximately, and fomula (2) can be adopted in fomula (1), then fomula (3) is got:

$$S = \ln(K_s) - \frac{1}{2}\sum x^T \cdot M_s^{-1} \cdot x \cdot P_i(x) \qquad (3)$$

For agonic estimation, fomula (4) can be drawn from fomula (3):

$$S = N/2 + \ln(K_s) = N/2 + N/2\ln(2\pi) + 1/2\ln(M_s) \quad (4)$$

where N is the amount of band. From fomula (4) we can know that entropy S is varied with the change of determinant of covariance matrix expressed by $|M_s|$. So the information content of a given band combination can be determined by the determinant of its covariance matrix.

In the pseudo-color composed image, three bands should be selected and red, green and blue colors should be assigned to display the image. Twenty schemes can be got if we select 3 from the 6 bands of TM (except Band 6), and the determinant of each combination scheme is computed and listed in Table 1. It can be found that the combinations of (Band 3, Band 4, Band 5), and (Band 1, Band 4, Band 5) are optimized and have the greatest information content, and (Band 3, Band 4, Band 5) is the best in most situations. The combination of (Band 1, Band 2, and Band 3) have least information content, which is consistent with the high correlativity of those three bands mentioned above.

In addition, Band 4 is always included in the former 6

Table 1 The determinant of each band combination scheme in Xuzhou mining area (in decreased order)

Urban area		West mining area		East mining area	
Band combination	Determinant	Band combination	Determinant	Band combination	Determinant
1-4-5	3.48E+06	3-4-5	1.71E+06	3-4-5	4.11E+05
3-4-5	3.18E+06	1-4-5	1.30E+06	1-4-5	3.45E+05
1-4-7	2.01E+06	4-5-7	8.93E+05	4-5-7	2.52E+05
3-4-7	1.65E+06	2-4-5	7.30E+05	2-4-5	1.72E+05
2-4-5	1.59E+06	3-4-7	6.77E+05	1-4-7	1.36E+05
2-4-7	9.53E+05	1-4-7	5.58E+05	3-4-7	1.32E+05
4-5-7	8.79E+05	2-4-7	3.37E+05	2-4-7	6.62E+04
1-5-7	7.33E+05	3-5-7	1.92E+05	3-5-7	3.59E+04
3-5-7	6.04E+05	1-5-7	1.51E+05	1-3-4	3.59E+04
2-5-7	3.54E+05	1-3-4	1.01E+05	1-5-7	3.56E+04
1-3-5	3.32E+05	2-5-7	9.53E+04	1-3-5	1.81E+04
1-3-4	2.58E+05	1-3-5	6.84E+04	2-5-7	1.73E+04
1-2-5	1.25E+05	2-3-4	4.49E+04	2-3-4	1.24E+04
2-3-5	9.38E+04	2-3-5	3.66E+04	1-2-4	9.66E+03
2-3-4	8.30E+04	1-2-4	3.15E+04	2-3-5	7.88E+03
1-2-4	8.15E+04	1-2-5	2.30E+04	1-2-5	4.89E+03
1-3-7	7.23E+04	1-3-7	8.71E+03	1-3-7	2.07E+03
1-2-7	3.31E+04	2-3-7	5.07E+03	2-3-7	1.02E+03
2-3-7	1.62E+04	1-2-7	3.69E+03	1-2-7	8.86E+02
1-2-3	1.72E+03	1-2-3	3.64E+02	1-2-3	1.88E+02

combinations in every sampling area, and the other can be selected from (Band 1, Band 2, Band 3) and (Band 5, Band 7). Further, Landsat TM information can be categorized into four sets: (Band 1, Band 2, Band 3), (Band 5, Band 7), (Band 4) and (Band 6). In the better combination schemes, set (TM5, TM7) and (TM4) are certainly included, and the best scheme is often the pseudo-color composed image of Band 3, Band 4 and Band 5. In order to get the best ocular effect, Band 3 should be blue, Band 4 green and Band 5 red in pseudo-color image, and the composed image is similar to natural color of the scene.

We also use Genetic Algorithm (GA) to this work and get similar results (ZHENG and PAN, 1999).

4 ANALYSIS AND COMPARISON OF RADARSAT IMAGE FILTERING METHODS

Speckle noise in SAR image is characterized by the exquisite change of gray, and that means some pixels are bright in an even region but others are dark. Speckle will decrease the spatial resolution of SAR image, hide its delicate structure, influence its interpretability seriously, and even cause the disappearance of some features. So it is vital to the use of SAR image and always an important issue in SAR applications to reducing and eliminating speckle noise by filtering.

4.1 Main Filtering Methods

The SAR image filtering algorithms in common use can be categorized into the following (CHEN *et al.*, 1999; FANG *et al.*, 1998; LI *et al.*, 2000; TANG *et al.*, 1996; WAKABAYASHI, 1996; XU *et al.*, 1996):

(1) Conventional methods. They include Median filtering, Mean filtering, Regional mean filtering and Sigma filtering, etc.

(2) Model methods. To suppose noise model and then process the image by relative filter, such as Kalman filtering and Lee filtering.

(3) Regional statistical adaptive filter. The adjacent pixels involved in filtering and their weights are determined by the regional statistical properties including histogram, mean, variance, gradient and others.

(4) Geometric filtering. A three dimensional model composed of plane location (row, column) and gray in image is established and morphologic method is used to reduce noise, for example, Gamma MAP filter.

(5) Wavelet based filtering. Firstly the image is decomposed of wavelet, then the approximate image representing the low frequency part in the image is processed by filtering algorithm, and detail image on behalf of high frequency part is processed by a given threshold in order to keep the main edge information, finally the image is re-constructed.

(6) Spectral filtering. Fast Fourier Transformation (FFT) is applied firstly, then relative process is conducted in spectral domain, finally Inverse Fast Fourier Transformation (IFFT) is used to return spatial domain.

4.2 Comparison and Analysis of Some Filtering Methods

In order to compare the effects of different methods, nine methods including Mean filtering, Median filtering, Lee filtering, Enhanced Lee filtering, Frost filtering, Enhanced Frost filtering, Kuan filtering, Gamma filtering and wavelet-based filtering, are used to filter a 1024×1024 Radarsat image, and Flat Index (FI), Edge Sustaining Index (ESI) and some common indexes are used to assess the filtering effects. The indexes are computed to every filtered image and listed in Table 2.

From Table 2, we can know that conventional median and mean filtering algorithm is not effective to Radarsat image filtering and adaptive algorithms are the most effective methods. By synthetic comparison and analysis we can know that Enhanced Frost method, Enhanced Lee method and Kuan method are more suitable for Radarsat. The wavelet-based method is effective also, but some issues including the selection of wavelet basis, decomposition layer and threshold should be researched further. Because different methods have different effects to different land cover, more studies should be given on the filtering algorithm selection oriented to specific task and region.

5 CLASSIFICATION METHODS OF SATELLITE RS IMAGE

Because of the uncertainty, unevenness and fuzziness in the phenomena and procedures of mining areas, traditional classification methods can't achieve satisfied precision and new methods should be proposed. In order to solve this problem, we propose some new methods and get higher precision than traditional methods. Those new methods include the BPNN-based classification and classification with support of GIS.

Table 2 Statistics of the characteristic of filtered images

Filtering method	Maximum	Minimum	Gray interval	Mean	Standard deviation	Entropy	Flatness Index			Edge Sustaining Index	
							Inhabitance	Farmland	Water	Horizontal	Vertical
Original image	255	0	255	14.9	15.2	3.4981	1.17	1.99	1.78	1.000	1.000
Mean filtering	143	0	143	14.9	10.4	3.2682	2.05	4.33	4.30	0.148	0.442
Median filtering	146	0	146	13.2	8.7	3.1418	1.96	4.68	5.22	0.241	0.349
Lee filtering	142	0	142	14.4	10.4	3.2651	2.02	4.15	3.52	0.259	0.419
Enhanced Lee filtering	253	0	253	15.8	13.9	3.3609	1.39	3.14	2.55	0.741	0.977
Frost filtering	229	0	229	14.8	11.3	3.2747	1.83	3.66	3.07	0.593	0.698
Enhanced Frost filtering	253	0	253	15.6	14.2	3.3740	1.32	2.95	2.49	0.815	0.977
Kuan filtering	143	0	143	14.9	10.4	3.2670	2.05	4.35	4.2	0.185	0.488
Gamma filtering	253	0	253	15.4	13.1	3.3312	1.43	3.20	2.89	0.685	0.884
Wavelet-based filtering	255	0	255	14.4	13.0	3.3293	2.17	3.01	2.91	0.702	0.457

5.1 RS Image Classification Based on Improved BPNN

Artificial Neural Network (ANN) has got rapid development and wide uses in RS image processing. Comparing with conventional methods, ANN can enhance the classification precision by 10% - 30%. Back Propagation Neural Network (BPNN) got wide applications.

Here we would like to adapt some improved methods including pre-processing of the input vectors, optimization of the network structure, adaptive and dynamic adjustment of leaning ratio, and introduction of momentum in order to increase the interval in weights. Two 512×512 TM images are selected for classification, the input neuron amount is 5, including the pixel gray of Band 4, Band 5, Band 7, PCA 1 of (Band 1, Band 2, Band 3) and *NDVI*(determined by$(Gray_{TM4} - Gray_{TM3}) / (Gray_{TM4} + Gray_{TM3})$); output neuron amount is 5, representing five classes including vegetation, water, building land, subsiding land and others; the neuron in hidden layer is 12. The classification precision is higher than that of conventional methods.

5.2 Classification Supported by GIS

The integration of RS and GIS is an important aspect of spatial information technology applications. In their integration, RS is used as the information source of GIS, and GIS is used to process and apply RS image, and also as the aided tool to RS image processing. Much work has been done on the topic on fusion of RS image and multi-source geographic data, image processing based on GIS and knowledge both in China and abroad. Nowadays, the universal thematic information extracting method is to view the object as a special class and identify it in classified image. The classification methods based on GIS can be described as follows:

(1) Layered classification. The study region is firstly divided into different layers according the GIS data such as elevation, slope and others, and then spectral feature (or gray information) is used to classify each layer.

(2) Combination of classification and layer division. RS image is firstly classified according to spectral features and then the results are processed again along with GIS data.

(3) Post-processing of classified image based on the knowledge discovered from GIS.

(4) Introducing GIS data into RS image processing directly.

Here we propose a layered classification method aimed at identifying subsiding land in mining areas. The method of layered classification supported by GIS is to categorize land cover into different layers according to specific criteria reflecting the characteristics of each object firstly, and then to apply relative classified methods to each layer according to its properties. The specific classified criteria are: 1) to categorize land cover into different layers according to their sensitivity to change based on field investigation and prior knowledge; 2) if land cover in one layer is hardly to change, the pixels in this layer are not processed and the class in GIS is given; and 3) if land cover in one layer is easy to change, the possible change forms are determined firstly and then effective bands and methods are used to classify this layer.

6 CONCLUSIONS AND PERSPECTIVES

In this paper, we give some studies and experiments on some key issues of applying Satellite Remote Sensing to mining areas and serving regional sustainable development. From the study, the following conclusions can be drawn:

(1) As far as Landsat TM RS image concerned, the combination of Band 3, Band 4 and Band 5 is the most effective to our study.

(2) The speckle noise reduction and filtering is very important to SAR applications. By the comparison to different methods, the adaptive filtering methods are proved the most effective. In addition, filtering based on wavelet transformation is also a good method.

(3) Classification of satellite RS image should adopt new methods and models. Classification based on the improved BPNN and GIS can get satisfied precision for applications in mining area, and those new methods may be used more widely in the future.

Although satellite RS can play important roles in mining areas, related studies is only in the beginning and many issues should be studied. In the future we shall continue to research those issues deeply so as to promote the application of satellite RS in mining areas, and that will further be used to resource and environment monitoring and Land Use/Cover Change (LUCC) analysis in mining areas.

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