APPLICATION OF TM AND SAR IMAGES FUSION FOR LAND MONITORING IN COAL MINING AREAS

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ABSTRACT:

The defection of single data source can be solved with fusion between TM and SAR images. It provides a better solution for land surface monitoring in the mining areas. Results of experiment showed that the fusion images can be integrated the advantages of each one, enhanced the recognition ability of features, improved land use/land cover classification accuracy. Further discussed the method of microwave remote sensing for ecological environment monitoring in mining areas, it is pointed out that the SAR images can be quantitative analysis of hydrogeological environment, the growth of crops and vegetation, land cover and soil resources, the INSAR images can be extracted collapse and change information. Research shows that the use of multi-source and multi-temporal images, fusion technology of TM and SAR images, could be favorable of dynamic monitoring for the ecological environment in mining areas, and provided basic data for exploitation of mining resources.

1. INTRODUCTION

Since large-scale mining and the impact of human activities, the ecological environment of the mining areas was severely damaged and these are reflected on the evolution of land surface characteristics. So the land surface monitoring and analysis has become a hot research, remote sensing technology as an advanced information collection at present, with the amount of information, low cost and short cycle characteristics and become very important technical means for the monitoring of mining areas (Du Peijun,2005). With the recent years, the unprecedented development of microwave remote sensing, active microwave remote sensing such as the synthetic aperture radar imaging has been widely applied. SAR not only has all-weather, all the imaging features, but also on penetrate detection for certain features, therefore, in the field of Earth observation is superior, and land cover mapping, ecology and agriculture, solid earth sciences, hydrology, sea Ice, and other fields also has a wide range of applications. At the same time, the use of synthetic aperture radar images can also extract elevation information and establish high-precision DEM. It has tremendous significance for researching the situation of collapse on the ground in mining areas.

2. SELECTION OF REMOTE SENSING DATA

The evolution characteristics of the mine land surface, mainly in the following areas: hydrogeological environment, crops and vegetation growth, land resources covering, soil and the collapse situation. Remote sensing data sources in the selection aspect should be considered above all characteristics. TM images with multi-spectral characteristics, but its low spatial resolution, and SAR image generally has a higher spatial resolution, spectral resolution but lower, if the SAR image

analysis combined with the corresponding region of TM images, can be integrated to reflect the reflective properties of visible light, near-infrared and microwave.

According to the evolution characteristics of the mine land surface, from land use and cover, soil, hydrology, geology, crop type, vegetation growth in the six selected parameters of radar images below in Table 1, in the table parameters for the flat area, the situation for different problems, the radar data under the parameters of research priorities to select. The paper selected Landsat ETM + images and ENVISAT data sources, see Table2.

Parameter Category	Resolution	Incidence angle	Polarization	Wave band
Land Use And Land Cover	Middle	Large	Multi polarization	Multiband
Soil Moisture	High	Low	Multi polarization	C/X or L/P
Hydrology	High	Low	Dual polarization	C/X or L/P
Geology	High-Middle	Large	Multi polarization	Multiband
Crops	Middle	Low	Multi polarization	C/X
Vegetation Growth	Middle	Low	Multi polarization	C/X

Table 1. Selection of Radar parameters for different features

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Data source （Sensor)	Wave band	Spatial resolution	Polari zation	Image position code	Imaging time
Landsat-7 （ETM+ ）	1-8	30	–	–	2001. 08.11
Landsat-7 （ETM+ ）	1-8	30	–	–	2005. 09.03
Envisat-1 （ASAR ）	C-Band	12.5	VV / HH	IS2	2001.6.29
Envisat-1 （ASAR ）	C-Band	12.5	VV / HH	IS4	2005.7.12

Table 2. Remote sensing data sources

3. REMOTE SENSING DATA PREPROCESSING

3.1 TM Data Preprocessing

The pre-treatment of TM images including geometric correct and optimal band combination. In the study area collected obvious 10 GPS control point of a uniform distribution, for the ETM+ images geometric correct, adopted Second Order Polynomial transform, and used three-dimensional convolution interpolation re-sampling, the precision of geometric correct was controlled of the RMS <0.5 pixels. The ETM+ optimal band were combined according to the study area topography, vegetation distribution, spectral reflectance characteristics. According to the index-related variance 、 correlation coefficient matrix, OIF index of the combination bands, in most cases, TM3, 4,5 and TM1, 4,5-band combination are the best, most detailed. In the TM345-band, roads, water, the residents, farmland and other places clear Comparison, better-performing and useful for the classification between features (Figure 1).
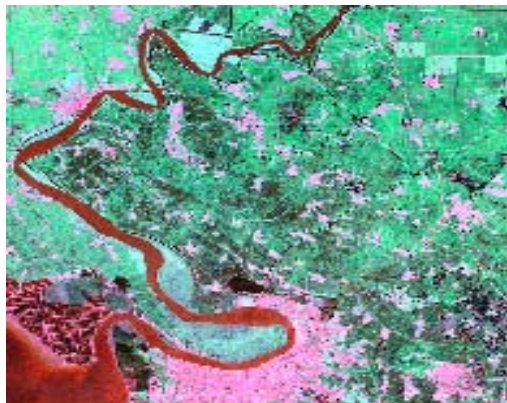

Figure 1. TM345-band combination images

3.2 SAR Data Preprocessing

As ENVISAR satellite imaging to be done in the course of coherent processing, and thus formed a signal to the noise, it made great impact with the interpretation of radar images, reducing the ability to identify targets and structure on the ground, making thematic feature extraction and classification of Obstacles, so need for Noise Reduction. After noise reduction, evaluated the filtering effect with smoothing index F and smoothing maintain index E of edge. F value is higher means that the ability smoothing stronger, E value is higher means that the ability to maintain higher, the formula is as follows:

$$F = M/S$$

$$E = \frac{\sum_{i=1}^{m} \left|(G_{R1} - G_{R2})\right|_{after\,filtering}}{\sum_{i=1}^{m} \left|(G_{R1} - G_{R2})\right|_{before\,filtering}} \quad (1)$$

The SAR data image pre-processing according to the landscape, the typical characteristics of surface features and ENVISAT data in the mining area. As the study area relatively flat terrain, a typical feature mainly vegetation, soil, water, the residents, farmland, respectively KUAN filtering, enhanced Lee filtering, enhanced filtering FROST, GAMMA filtering done a test. Texture complex information to residents, attention should be paid in noise reducing, at the same time try to avoid the loss of texture information leading to the fuzzy of brink; farmland relatively homogeneous, not too rich texture information, speckle easy to filter out, but to maximize the ability to maintain the edge; water for the homogeneous region, regardless of ability to maintain the edge. Taking all these factors, according to smoothing effect and maintain ability of the edge after noise reducing to choose the enhanced Lee filtering (Figure 2, Figure 3).
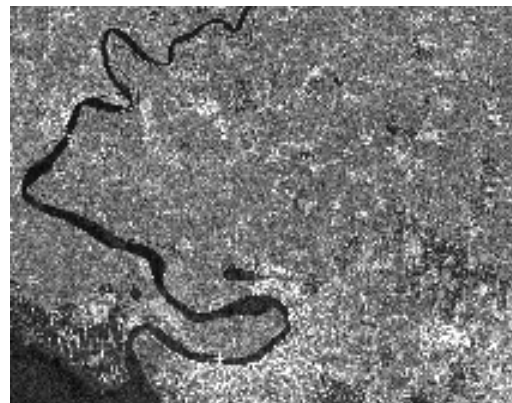

Figure 2. Original SAR image

Figure 3. Enhanced Lee filtering

3.3 TM and SAR Image Registration

Image matching error is impacted with results on land-use change monitoring, to get reliable analysis results of the images need high match accuracy. As a matching error of the element space will result in 50 percent of the false changes. To control the error rate of 10 percent, matching error on the image must be less than 0.2 pixel, or more like small, the prerequisite and basis of remote sensing image fusion is the registration for multi-source remote sensing images, the registration error requirements less than one pixel. TM and SAR image resolution were 30 meters and 12.5 meters, a greater difference, and the SAR images have noise dot, in order to improve the accuracy of registration, uniform selection for homonymy points, as clearly building, rivers changes smaller, texture is clear such as roads for the registration, a total of 26, using a polynomial correction, the error in control as 0.3 pixel. It was satisfied for the registration accuracy requirements in the test.

4. TM AND SAR IMAGE FUSION

TM images received surface features information by the electromagnetic spectrum stretching from 0 to 255 between the Gray values; SAR images recorded form 0 to 65535 between the integer values in the microwave band features the return value, different Gray Represents the relative characteristics of different features. The homology sensors, can direct use of video Gray value integration and subsequent processing, and sensors for different sources, because of its imaging, spectral range and the characterization of surface features and other characteristics are different, then different images Gray value was not comparable, pixel Gray value for fusion will bring about the corresponding error. Sensor characteristics need to, through the use of physical corresponding model and the reflectivity of the true features and value after the scattering, accordingly for images fusion and information extracted.

The SAR and TM images using the fusion algorithm integration of wavelet and HIS, its integration with the basic approach: the largest amount of information on the composition of the TM5, TM4, TM3 for IHS transform, I get the strength component wavelet transform, using the wavelet function for Sym4 wavelet. SAR image and the image I used Sym4 wavelet for a wavelet decomposition, with the approximate SAR images AS replace the approximate I image AI, to impose anti-wavelet transform to generate I' image and then IHS inverse transform, and you will get a new fusion images of R'、G'、B' (Figure 4).

Figure 4. Fusion of TM and SAR images

5. MINE TYPICAL FEATURE EXTRACTION

According to the fusion of SAR and TM images, classified the mining area features. In order to enhance the classification results credibility of features, using remote sensing feature of the land cover information from the tiered approach that, according to the different and various targets Characteristics, take the appropriate information extraction methods, respectively, the establishment of thematic information layer, and then merger the thematic information layer to the overall classification, hierarchical extraction methods to take fully into account the different characteristics of typical features, the results of the classification can be making area measurement、 accuracy estimates, such as change detection analysis, and generate thematic maps throughout the category.

According to the land surface monitoring purposes, the study area is divided into hydro-geological environment (include natural water and geological conditions), agricultural land (include grassland, paddy fields, dry land, others) and vegetation growth, land use and land cover (include traffic, residents, Mining land, forest land) and soil conditions as several major categories. The special features which not recognized by the fusion images, to further explore the solution method of microwave remote sensing and interference SAR images.

(1) Water extraction (canals, reservoirs, ponds and stagnant water of the collapse)

Waters of the study area include canals, reservoirs, ponds and stagnant water of the collapse, can exclude the water impact from the mountain shadows and the shadow of buildings. On the basis of the results from water extraction, conducted extraction of canals, reservoirs, ponds, according to the differences characteristics in space, such as canals were bending the long strips; reservoir area are relatively large, border is relatively smooth; ponds shape are sleek, oval or rules similar to the quadrilateral. Because microwave remote sensing particularly sensitive to water, on the radar vegetation canopy soil or snow cover has some penetration, we can detect these objects on the surface and sub-surface information, so it can use the SAR images for the water body Monitoring.

(2) Building land extraction (urban land, rural settlements, an independent mining site, transportation sites)

Towns, settlements, land transport and mining sites are easy to distinguish from the fusion images, the merits to retain the spectral characteristics of TM images, but also retained texture information of the high-resolution SAR images.

(3) Green space and farmland extraction (paddy field, dry land)

The study areas include green woodland and grassland, farmland including rice fields and mainly dry. In the TM images similar spectrum information, information also is not very clear after the fusion, distinction between the regional crops can use SAR images to distinguish between them by scattering differences, related to integrated data, will distinguish types of crops.

(4) Mining subsidence land extraction

As Mining long time and scope, ground subsidence is quite serious, especially in the rainy season there are stagnant water

in collapse, surface-to-dot patterns. From the spectral characteristics analysis, due to the fact that subsidence land are composed of green space, wasteland, water and building land, its spectral characteristics can not describe as a unified model, based on the direct use of spectral characteristics is very difficult to extract. The SAR and TM images can not form stereo images, failed to achieve the elevation monitoring, and the elevation changes in land surface mining area is the main evolution form - the essential feature of the ground collapse, then we can use interfere SAR images to establish DEM, while use the existing DEM data to compare the measured values of interfere with the levelling/GPS measurements, analysis of interfere measurement accuracy used to the surface deformation, finally, get ground subsidence rate change map and changes circumstances.

(5) Vegetation growth and soil moisture information extraction

Different crops have their own geometric Structure, canopy roughness and moisture content. The different parameters after the scattering are very sensitive in radar images. At the same time a different crop growing season, the geometric structure, canopy roughness, the water content is also different, can also use these indicators to assess phase change of crop parameters; when the soil moisture content changes, it will changes in dielectric properties, radar is very sensitive to this, so radar images can also be used for the assessment of soil moisture.

(6) Surface features changes extraction

Features change detection of the adjacent phase has two methods with the comparison after classification and image difference comparison. At present major research focus on the help of background knowledge in the GIS for extraction. Comprehensive previous research results, the paper adopted a hierarchical method of extracting information changes, through the creation of knowledge and decision tree approach to land information change detection, established the main features characteristics of the evolution type. Such as: farmland and a stack of arable land, cultivated land in the area from the morphological changes in the region (only extract to reduce region), and then extract the changes in the region, with green space, construction, land subsidence and to conduct analyses and judgments if construction sites were in the area.

6. RESULT AND OUTLOOK

Using Landsat ETM + and ENVISAT fusion images for land surface information monitoring in mining area, established the land resources remote sensing classification system, and comprehensive results of previous studies on the extraction of land resources in the mining area. Further discussed the method of microwave remote sensing for ecological environment monitoring in mining areas, it is pointed out that the SAR images can be quantitative analysis of hydro geological environment, the growth of crops and vegetation, land cover and soil resources, the INSAR images can be extracted collapse and change information. Research shows that the use of multi-source and multi-temporal images, fusion technology of TM and SAR images, could be favorable of dynamic monitoring for the ecological environment in mining areas, and provided basic data for exploitation of mining resources.

REFERENCES

References from Journals:
Ge, L., X. Li, and C. Rizos,2002. GPS and GIS sssisted radar interferometry. *Advanced International Workshop on InSAR for Measuring Topography and Deformation of the Earth Surface.* Hong Kong, pp. 16-17.

Peng Suping, Wang Lei,2002. Monitoring the seeper subside in coal district by the remote sensing. *Journal of China Coal Society,* China, pp. 374-378.

Rizos Chris, Ge Linlin, Nesbitt Andrew,2003. The integration of GPS, satellite radar interferometry, and GIS technologies for ground subsidence monitoring. *In Spatial Science*, *Canberra*, Australia, pp. 22-26.

Strozzi, T., Wegmuller, U., Werner, C.,2001. JERS SAR interferometry for land subsidence monitoring. *The 3rd International Symposium on Retrieval of Bio and Geophysical Parameters from SAR Data for Land Applications,* Sheffield, UK, pp. 11-14.

Xie Hongquan, Hu Zhenqi,2004. Classification system of land use/cover in mining area based on RS. *Journal of Liaoning Technical University*, Fuxin, China, pp. 721-723.

References from Books:
Du Peijun, Hu zhaoling,2005. *A study of the monitoring and modulate of terrestrial surface evolution in mining areas.* Geological Publishing Company, Beijing, China, pp. 33-40, 92-96.

Guo Huadong,2000. *Theories and application of Radar for earth observation*. Science Press*,* Beijing, China, pp. 222-234.

Yu Yaqiu,2005. *Theory and method for data validation of space-borne microwave remote sensing*. Science Press*,* Beijing, China, pp. 236-242.