

MONITORING SUBSIDENCE AREA IN MINE BASED ON MULTI-SOURCE AND MULTI-TEMPORAL REMOTE SENSING DATA

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ABSTRACT:

In this paper, the decision-making information of subsidence area for twenty years is extracted, using Landsat multi-band and multi-temporal remote sensing data, SPOT 5 texture features, DEM elevation, the methods of data fusion and principal component analysis and GIS technology, thereby the spatial and temporal distribution of change of subsidence area in mining is acquired from years 1987 to 2007. The changes of subsidence area are larger from 1987 to 2000, accounting for 86.25% of the total subsidence area; the changes of subsidence area are smaller from 2000 to 2007. The subsidence area reclaimed for fish ponds, other villages and so on.

1. INTRODUCTION

The stability of the overlying rock was undermined by exploited the coal resources in large-scale, it is result in the surface subsidence, collapse. Surface subsidence caused by coal mining has two manifestations: on the one hand, it not only leads to surface cracks or collapse of the buildings, but also affects the tillage conditions of the local crop. On the other hand, mine water drainages into the lakes and ponds; the pollution of surface damage has become a major pollution source to the production and living around the mining area. How to effectively monitor and avoid these hazards caused by the surface deformation, improving the capacity of emergency response the collapse has become a serious problem to be solved. At present, in the mining area scale, the conventional methods (such as measuring of surface deformation) is with high cost, there is no unified standard, and not establish a set of feasible continuous monitoring data to obtain subsidence area, so nothing can provide sufficient data and technical support to the evolution of ecological environment in mining area.

Currently, using remote sensing technology to extract subsidence area information is the direction of the study. Wang Bao-cun, et al. (Wang Bao-cun, 2007) used TM and CBERS data to dynamic monitor the water of ground subsidence of kailuan coal; DU Pei-jun et al. (DU Pei-jun, 2003) designed the reliable classification and models to extract and make recognition of collapse of mining. However, due to the limitations of resolution, the information extraction of subsidence area has certain difficulties, the mainly problems: Remote sensing data is two-dimensional data, it is difficult to define the border; Collapse occurred is a gradual process, it is difficult to express information of elevation changes; Subsidence area is covered by water body, and its border is not uniform with the non-subsidence border; The problem that vegetation information is difficult to distinguish led to difficult to determine the slight collapse border. With the occurrence of high-resolution remote sensing data as well as the combination of remote sensing technology and GIS development, it becomes possible to solve the above questions. This article uses remote sensing technology, SPOT texture features, DEM elevation, and

the methods of data fusion and multi-decision rules, to extract the information of the changes of subsidence for the past twenty years. Thus timely makes forecasts the regular of the temporal and spatial distribution and all-round and three-dimensional of subsidence area which caused the ecological environment change.

2. DATA FUSION

2.1 The causes and characteristics of subsidence area

(1) To form a number of ground subsidence, ground fissures
In remote sensing images, there are sizes of subsidence and ground fissures in the area of goaf and subsidence which showing dark linear features, their directions are inconsistent with the directions of agricultural cultivation, they are belonging to non-artificial behavior. These characteristics have caused great damage to the surface. The field verification found that: These dark linear features are the results of spectral difference of terrain mutation with management roofs using the method of fall and subsidence caused by micro-goaf scarp topography. The types involved parallel, polyline and worms. There are quite large ones with a scale of the number of meters wide and several hundred meters long.

(2) Water body collapse

The depression and hydrops formed in the long-term of ground settlement, coupled with the increase of mining depth, as well as the increase of displacement of the pit which made the water area change. New water or the changes of original water are calculated by comparing different phase remote sensing data, which is an important basis of the subsidence changes. In addition, the shapes of collapse surface water are irregular, which have clear features with artificial excavation. There are artificial fish ponds in the edges of collapse. They mainly distribute near the mining area, the features of the western mining area are more obvious.

(3) Emergence the signs of land degradation

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Subsidence and ground fissures make groundwater seepage,

suppress irrelevant information and to improve image environment of target

Sensor	Scene number	Time	Band number	Spatial resolution	
				multispectral bands	panchromatic band
TM	p122r35	1987.09	7	30m	
ETM	p122r35	2000.04	8	30/60m	15m
SPOT5		2007.09	5	10/20m	2.5m
SRTM	p122r35	2000.02	1		90m

Figure 1. The control points of geometric precision

causing the water level dropped; forming new land degradation. The original large areas of irrigated land had to switch to other crops or the types of land reclamation, such as poplar forest, shrub and so on. The characteristics are more obvious on SPOT 5 image (YANG Sheng-jun, 2006). Distribution associated above the mining area.

(4) Changes of ecological landscape

Due to ground subsidence, the original landform types or vegetation types have some changes, such as: agricultural land changes into water body; cultivated land changes into shrub land and woodland; green winter wheat field changes into the barren bare land.

To sum up, the main changes of subsidence area are reflected by the spectral characteristics and elevation change. Therefore, this paper intends to make use of data fusion (principal component analysis) and decision tree to extract the information of changes.

2.2 Theory and methods of data fusion

Image data fusion is a process that fusing multi-sensor image data and other information. In order to highlight the collapse area, we focus on computing and processing multi-source data, which is space or time redundancy or complementary, according to principal component analysis to obtain more accurate and extensive information than any single data, generating a fused image with the new space, spectral and time characteristics.

K-L transformation is applied to many remote sensing fields, it has superiority in information extraction, integration and change detection. The essence of K-L transformation is removing the redundancy, making the other information into a small number of images (that is, the first three principal components), then generalizing mass images and eliminating the relevance. In order to achieve the purpose of removing redundant, K-L transformation using correlation coefficient array or covariance matrix to eliminate the relevance of original images. For the fused image, the contributions information of each band is maximizing performed out.

The advantages of K-L transformation are that it can be able to isolate the information and reduce the related features which can highlight the different objectives. In addition, it can automatically correct the radiation differences; so there is no need to deal with the relative radiometric calibration. It is not a simple composite of the data, it emphasis on the information optimization to highlight the useful information, to eliminate or

recognition, thereby increasing the reliability of interpretation, reducing ambiguity and improving the results dynamic monitoring.

Because the texture features and structure information of the high-resolution data is abundant, first of all, it makes up for the lack of elevation data; and TM data provided a wealth of spectral features for collapse information. Using multi-temporal remote sensing data and non-remote sensing data and the method of decision-making tree, the macro characteristics changes of subsidence area are extracted with time and spatial distribution.

3. CASE STUDY

Essence: In a unified geographical coordinates, a new and more effective image that represent the target information will generating using some algorithm for the number of remote sensing image data which are detected for the same target.

Objective: Multi-band information of a single sensor or information of different types of sensors is integrated, so the redundancy and contradictions that may exist in multi-sensor data are eliminated, and complement to each other. It is not improved the betimes and reliability of information extraction, but improved the use efficiency of data.

3.1 Data sources, methods and steps for integration

In this paper, the subsidence area in Shandong mine is dynamic monitored based on remote sensing data including remote sensing sources TM, ETM, SPOT 5; SRTM and measured data, the parameters of data are shown in Table 1.

The region of low mountains and hills in western Shandong is the study area, the terrain of northeast is higher than southwest, it belongs to the zone of the half-humid monsoon climate. The length from east to west is about 22 kilometres and the width from north to south is about 2 ~ 5 kilometres. At present, there are seven coal mines, such as Daifeng coal mine, Yangzhuang coal mine. The annual production of raw coal around 6.5 million tons. In the process of coal mining, it is manifold that triggered the problem of ecological environment, and impact on local residents' surface is the changes of subsidence area.

3.2 Data pre-processing

The test uses different data sources to integration; therefore, it is very important to registration before the integration.

Spatial registration is the premise of integration which aimed at eliminating the differences caused by shooting angle, different phase or resolution from different sensors. In this paper, the space registration includes the registration between 1987 TM and 2000 ETM and the registration between 2000 ETM and SPOT 5 data.

The steps of spatial registration as the following:

- (1) Feature selection: choosing obvious characteristics in the two images for registration, such as borders, cross-line-like points, regional contour lines.
- (2) Feature matching: finding corresponding obvious features

points from two images as control points by using of certain registration algorithm.

- (3) Spatial variation: establishing the mapping relation between images according to the control points.
- (4) Interpolation: re-sampling of the non-reference image according to mapping relation, and then obtaining registration

Point #	Point ID	X Input	Y Input	X Ref.	Y Ref.	Type	X Residual	Y Residual	RMS Error
24	GCP #24	462234.712	4007667.660	461975.380	4009433.245	Control	0.172	-0.376	0.413
25	GCP #25	458897.914	4006080.986	458723.979	4007840.808	Control	-0.031	0.220	0.222
26	GCP #26	459294.736	4008837.105	459088.541	4010599.917	Control	-0.388	0.097	0.400
27	GCP #28	464090.136	4009645.319	463796.666	4011421.036	Control	-0.004	-0.031	0.031
28	GCP #29	467168.083	4009443.265	466845.827	4011234.003	Control	0.129	-0.089	0.157
29	GCP #30	461894.489	4012110.370	461645.412	4013873.746	Control	-0.268	-0.262	0.375
30	GCP #32	462170.629	4002108.727	462006.552	4003838.237	Control	-0.134	-0.044	0.141
31	GCP #31	471969.585	4005293.881	471670.658	4007080.893	Control	0.093	-0.094	0.132
32	GCP #34	469842.874	4004296.767	469556.278	4006060.958	Control	0.076	0.070	0.103

Table 1. The parameters of satellite image

image with the reference image.

The accuracy of space registration is required within 0.5 pixels. The most critical and most difficult step in spatial registration is finding obvious features as control points though feature matching. The control points of geometric precision are shown in Figure 1.

3.3 The method of data fusion

The two test schemes as following:

- (1) The fusion of ETM 543 bands in 2000 with TM 543 bands in 1987.

Firstly, making histogram matching between 543 bands in 2000 and 543 bands in 1987, getting the enhanced image. Secondly, fusing 6 bands of enhanced image and doing principle component transformation; The fusion image is shown in Figure 2, in the image, the yellow spots are the variations.

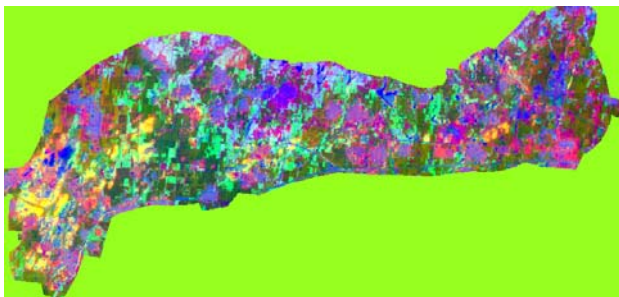


Figure 2. The Synthesis of PC4, PC3, PC2 of data fusion

- (2) The Synthesis of the SPOT band3 in 2007 and ETM + 543 bands in 2000.

First of all, making histogram matching between high resolution band3 in 2007 and the first principle component of TM in 1987, getting the enhanced image.

Secondly, the first principle component of TM in 2000 was replaced by the enhanced image.

And then PC2, PC3 of TM in 2000 were synthesized with the above image, the fusion image is shown in Figure 3, in which the nattier blue pots in blue circles stand for variograms.



Figure 3. Spot B3 and PC2, PC3 of year 2000 data fusion

3.4 Information extraction

The changes information was extracted using decision tree from the fusion images. The fusion image and extracted image were established in different layers by GIS software, and then the changes of subsidence area were acquired.

3.5 The regular of the spatial distribution of subsidence area

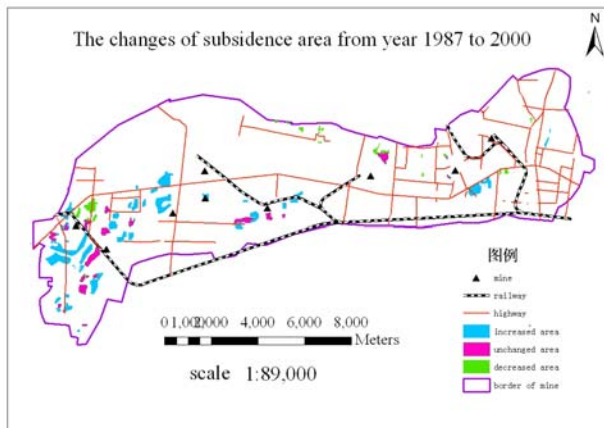


Figure 4. The changes of subsidence area from 1987 to 2000

The subsidence area mainly distributed in the western mining region, and subsidence area increased much from 1987 to 2000, it is shows that the new mining exploitation area was mainly in the western and the depth of the western coal was great and required more drainages; the subsidence area located in the south western has a relationship with the terrain (high-northeast, low-southwest), the subsidence area did not have much reclamation.

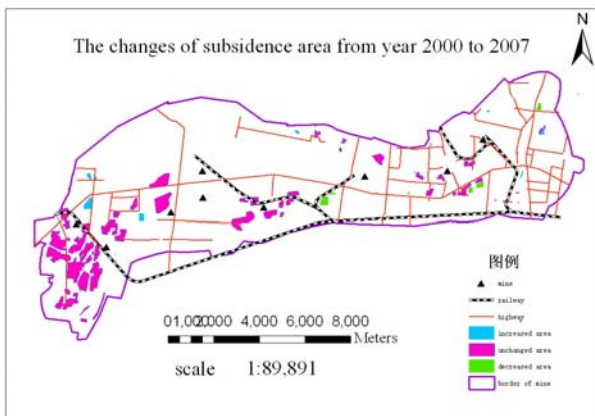


Figure 5. The changes of subsidence area from 2000 to 2007

The Figure 5 shows that the unchanged of subsidence area is larger from 2000 to 2007; however, in the eastern of the mine, the subsidence area was back filled and established new villages which realized land reclamation.

4. CONCLUSIONS

It is feasible to monitor the collapse zone information for using remote sensing methods. The changed information of subsidence area is obtained by the methods of decision tree and data fusion.

1. The change information of subsidence area in two phases was obtained based on multi-band and multi-temporal remote sensing data using the method of data fusion.

2 The changed information of subsidence area is extracted by the method of decision tree combined with GIS.

3 The change regular of the mining area was given. During years of 1987-2000 the changes of subsidence area are larger than years of 2000-2007, accounting for 86.25% of the total subsidence area; during years of 2000-2007, the subsidence area reclaimed for fish ponds, other villages and so on. It is not only provides basic data for evaluation and reclamation the ecological environment of mining, but also provides technical support for the decision-makers to make related measures.

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