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Feature Extraction System for Land Cover Changes Based on Segmentation

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Abstract : This study focused on providing a methodology to utilize temporal information obtained from remotely sensed data for monitoring a wide variety of targets on the earth's surface. Generally, a methodology in understanding of global changes is composed of mapping, quantifying, and monitoring changes in the physical characteristics of land cover. The selected processing and analysis technique affects the quality of the obtained information. In this research, feature extraction methodology is proposed based on segmentation. It requires a series of processing of multitempotal images: preprocessing of geometric and radiometric correction, image subtraction/thresholding technique, and segmentation/thresholding. It results in the mapping of the change-detected areas. Here, the appropriate methods are studied for each step and especially, in segmentation process, a method to delineate the exact boundaries of features is investigated in multiresolution framework to reduce computational complexity for multitemporal images of large size.

Key Words : Feature, Extraction, Segmentation, Channge Detection, Multiresolution Framework.

1. Introduction

Natural land cover continuously undergoes changes impacted by natural disturbances such as fires and floods as well as human activities such as urbanization and agricultural activity. It is important to detect land cover change, investigate the factors to cause them and produce predictions about long-term dynamics for the sake of environmental management. Remote sensing by satellites has provided a timely and cost-effective source of land cover information and become an important tool for monitoring changes on the earth's surface, such as status of vegetation, urbanization, degradation and many other landscape phenomena, because remotely sensed imagery contains various levels of information over a large area. In addition, it also makes long-time environmental monitoring possible allowing a quantitative measurement of the state of the landscape at any point in time. For this, remotely sensed data are processed and analyzed utilizing various landscape models in regional to global scale.

This study focused on providing a methodology to utilize temporal information obtained from remotely

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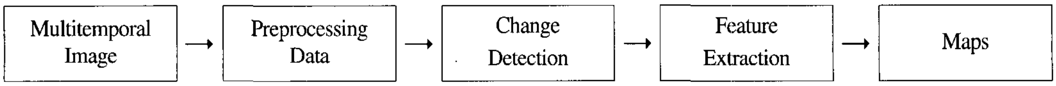


Fig. 1. Change Detection and Feature Extraction Process.

sensed data for monitoring a wide variety of targets on the earth's surface. The methodology in the study of global changes is generally composed of mapping, quantifying, and monitoring changes in the physical characteristics of land cover. A variety of digital image processing techniques are utilized to characterize and analyze features in the data. The selected processing and analysis technique is one of the factors which affect the quality of the information. In this research, feature extraction methodology for detection and mapping of land-cover changes is proposed based on segmentation, resulting in the mapping of the change-detected areas. The process for it is described shortly as follows:

Preprocessing is composed of radiometric and geometric calibrations and corrections, which are fundamental operation to remove remote sensing instrument artifacts and atmospheric path degradation (Song, 2001; Chavez, 1996). In this study, absolute and relative atmospheric correction methods are shortly described with the analysis case to require the radiometric correction. Then, the change detection is carried out by subtracting the corresponding pixel values of multitemporal images. Finally, a segmentation/classification is applied to the resultant difference layers to extract features. In these processes, meaningless results, so-called noises, are removed with the help of thresholding based on the histogram of normal distribution with zero mean.

Here, the region-based segmentation method is selected to identify the boundaries of the change-detected areas and enable extraction of each aggregated region. Since remotely sensed imagery is naturally of large size and multitemporal images are to be processed, a method to reduce computational complexity is preferred. Multiresolution framework permits processing at different resolution: properly large, coarser regions are segmented at low resolution and detailed boundary regions at high resolution, since the interior and boundary regions can be separated at higher levels. In this study, a multiframe segmentation approach based on the anisotropic diffusion pyramid afforded by the nonlinear smoothing of anisotropic diffusion is considered for accurate boundary delineation of extracted feature (Acton *et. al.*, 1994). Furthermore, anisotropic diffusion yields intra-region smoothing compared with other pyramid structure usually producing inter-region smoothing (Burt *et. al.*, 1981).

This paper is organized as follows: Section II describes key processes which constitute a change detection and feature extraction and then the performance of the algorithm is tested and evaluated with a subset image of Landsat TM in Section III. Finally, some conclusions and further work are mentioned in Section IV.

2. Feature Extraction Methodology

The feature extraction system to detect land-cover changes from the multitemporal remotely sensed data and to extract the detected features as aggregated regions is shown in Fig. 2.

1) Preprocessing

Satellite sensors collect the modified version of the electromagnetic radiation signals due to the scattering and absorption by gases and aerosols from the earth's surface to the sensor. Radiometric correction is a

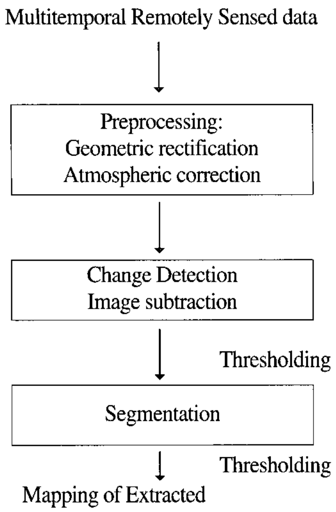


Fig. 2. Constituent processes in feature extraction system.

difficult, yet necessary step to correctly utilize the temporal information contained in the spectral data. In processing of multitemporal data set for land use/land cover change, applying the same analysis method to individual images assumes the same bright value distribution for the stable classes and requires radiometric correction due to sensor degradation and atmospheric attenuation, such as the case that image segmentation is applied to each differenced image. Generally, whether atmospheric correction is necessary or not depends on the methodology utilized in applications, which can be briefly summarized in Table 1.

Various correction methods are used to put the images on the same radiometric scale, which are categorized into absolute and relative approaches. While in absolute correction, a digital number is converted to surface reflectance after atmospheric correction, the same digital number in corrected images is considered as the same reflectance regardless of the actual reflectance value in relative correction. The darkest pixel improvement method is the simplest absolute approach (Chavez, 1988; Chavez, 1989), where the minimum value of the image is subtracted from all the pixels; it is considered to be due to the atmospheric effect. In dense dark vegetation approach, atmospheric optical depth is retrieved based on the relationship between reflectance of mid-infrared and that of blue and red spectra for dense dark vegetation (Kaufman, 1997).

Relative atmospheric correction utilizes the linear relationship between the corresponding bands among successive images, not depending on actual optical properties. First, identify the pseudo-invariant features over the image and determine the linear relationship using their spectral values. Then, normalize all the images to the reference image based on this linear relationship. Various multitemporal images such as Landsat TM, SPOT, and MSS were successfully normalized with properly selected pseudo-invariant features in many change-monitoring researches (Michener and Houhoulis, 1997; schott *el. al.*, 1988).

In a hybrid method, absolute calibration is also applied together with relative method in such that multitemporal images are individually normalized to the reference image and then, absolute approach is applied to them (Song, 2001). In addition, many other correction

Table 1. Requirement of atmospheric correction according to image analysis method.

Atmospheric Correction	Image Analysis Method
Not required	- Usage of a single date data. - Change detection based on the classified results after each image is individually classified. - Usage of a composite image which has multitemporal data in single data set after geometric rectification. - Image differencing pixel by pixel
Required	- Analysis assuming the same radiometric characteristics in multitemporal imagery.

methods are further developed based on these basic approaches. It is reported that the complex algorithms don't consistently provide better results, and all correction algorithms improve the data analysis.

2) Change Detection

The temporal information contained in the spectral data of successive images can be detected with help of radiometric correction. The change detection is performed by subtracting the corresponding pixel values of multitemporal images. At this time, the appropriate bands that best separate certain difference can be selected from multispectral images. For instance, in the case of detection of burned areas, the near-infrared bands give the best results since ash is highly absorptive and vegetation is highly reflective.

In a differenced image, no-change areas show near-zero values and change areas manifest difference values. However, the noisy information which can not be regarded as the change is also included. A thresholding technique is applied to the difference image to remove the undesirable noisy values, which is based on a histogram of normal distribution with zero mean.

3) Feature Extraction Using Segmentation Based on Anisotropic Diffusion Pyramid

In a difference layer obtained from an image sequence, in general, the detected areas are not enclosed by significant edges and don't form the meaningful features; This is due to spectral error in the image source as well as the applied radiometric correction. The feature extraction system includes region-based segmentation/classification process that is applied to the pixel-based difference layer for region aggregation, resulting in a map of the extracted features for land cover changes.

In segmentation/classification, a methodology to delineate accurate boundaries is to be considered. In addition, the technique to reduce the computational cost is required since the remotely sensed data are generally very large and multitemporal images are to be processed. One way to increase the speed of an image analysis algorithm is to reduce the volume of input data. This approach is naturally related to the concept of multiresolution framework (Rosenfel, 1984). Furthermore, it is pointed that multiresolution representations often produce better results in edge detection and region-base segmentation/classification (Rosenfel, 1984). In multiresolution structure, the original high resolution image is at the lowest level and successive levels represent the image of decreasing resolution. Multiscale segmentation approach allows aggregated regions at different resolution and properly segments large, homogeneous regions and detailed boundary regions since the interior and boundary regions can be separated at higher levels.

The Gaussian pyramid is generally utilized in segmentation (Burt *et al.*, 1981) where the initial pyramid levels are constructed through averaging the values of corresponding nodes in previous lower level and image segments are represented by son-to-father links. The inter-level smoothing in the Gaussian pyramid tends to blur and distort region boundaries with increasing levels. The pyramid segmentation method based on the anisotropic diffusion is afforded by the nonlinear smoothing of anisotropic diffusion (Perona and Malik, 1990). The anisotropic diffusion pyramid produces intra-region smoothing which can preserve both boundary and intensity information (Scott *et al.*, 1994). Resolution transformation can be carried out with a progress by the heat diffusion equation in the following,

$$S_{i,j,t} = div(c_{i,j,t}\ \nabla S) \tag{1}$$

where ∇ is the gradient operator, div is the divergence operator, and $c_{i,j,t}$ is the heat diffusion coefficient at site (i,j) and iteration t.

Anisotropic diffusion where diffusion is allowed to vary according to the magnitude of the local gradient is

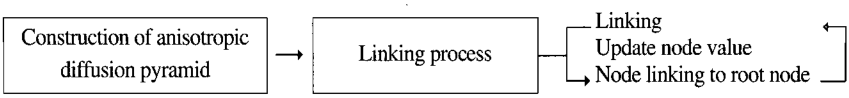


Fig. 3. Segmentation process using anisotropic diffusion pyramid.

usually operated in four directions (N, S, W, and E) as in Eq. (2).

$$S_{i,j,t+1} = S_{i,j,t} + \Delta(c_N \nabla_N + c_S \nabla_S + c_E \nabla_E + c_W \nabla_W) \quad (2)$$

$$\nabla_N = S_{i-1,j,N} - S_{i,j,N}$$
$$\nabla_S = S_{i-1,j,S} - S_{i,j,S}$$
$$\nabla_E = S_{i-1,j,E} - S_{i,j,E}$$
$$\nabla_W = S_{i-1,j,W} - S_{i,j,W}$$

where c is the function of the differenced value of the neighboring pixels and calculated as follows:

$$c_N = g(\| \nabla_N \|) \quad (3)$$

There are many possible choices for g(·) depending on the extent of smoothness. Nonnegative monotonically decreasing functions can be utilized such that neighborhood smoothing is inhibited at the boundary areas where the local image gradient is large. In this study, the following equation,

$$g(\| \nabla_N \|) = \exp(-\left(\frac{\| \nabla \|}{\eta}\right)^2) \quad (4)$$

is utilized, where η is a scale parameter to control the effect of the nearest neighbor difference, ∇. This can preserve boundary and spectral information between resolution transformations.

The segmentation is accomplished by constructing pyramid structure with successive anisotropic diffusion of the original image and then linking nodes each level to the final node at root level as shown in Fig. 3. The initial pyramid is obtained according to anisotropic diffusion described in Eq. 2.; the node value at (i,j) of level l is initialized by anisotropic diffusion result in the four direction at $(2i, 2j)$ of level $l-1$. The root level can be selected for segmentation and thus, the root level determines the number of final segments. Linking process where node values are updated and each node is linked to one of the root node is iteratively performed; each node is linked to the father that has the root value closest to its value, the node value is updated based on the node values of its sons, and finally, root values are assigned to the descendent nodes successively.

3. Experiments

The proposed approach was implemented and tested. To evaluate correction methods to put the images on the same radiometric scale and correction effect on change detection, Landsat TM data are utilized as sample data set, which include various regional characteristics such as river, urban area, and developmental region. For the accuracy test, maximum likelihood classification is applied, when the training data comes from one of two images obtained on different dates (1988, 1989) and the other image is classified with them. The results of three methods are compared in Table 2: the darkest pixel

Table 2. Comparison of classification accuracy (%) using different correction methods.

Image for training data	Image for classification	Raw data without correction	The darkest pixel improvement method	Dense dark vegetation approach	Ridge method
1988	1989	42	54	58	58
1989	1988	36	52	46	56

Fig. 4. Comparison of the extracted features: (a) 256x256 TM sample (b) Original feature extracted manually (c) Extracted feature through anisotropic pyramid with level 3 (d) Extracted feature through anisotropic pyramid with level 4.

improvement method, dense dark vegetation approach, and Ridge method.

All correction methods improve classification accuracy compared to the results without correction. It is noted that it's difficult to select the method which consistently performs best and the algorithms based on the complex theory don't also give the best results at all times. In land cover change detection to monitor large area with multitemporal data, the methods which are computationally cheap and provide the good results are preferred. Darkest pixel improvement method is simple but one of the best working correction methods, which have been employed in many applications. In the case that the surface reflectance value is known for certain vegetation type, first, mutitemporal images are relatively corrected and then each image is normalized to the referenced reflectance values.

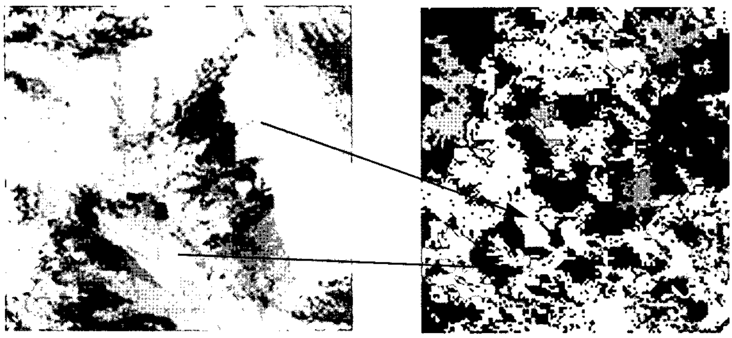
The performance of segmentation methods are tested with remotely sensed data. A subset of band 4 of Landsat TM is selected as test area which includes geographical regions. First, the ground truth feature of a geometrical region is extracted manually from a test image as in Fig. 4 (b) and then compared with the results extracted through segmentation implementation in Fig. 4 (c) and (d).

Next, the deviation of the segmented feature from the original feature was numerically evaluated. For this, two features were overlapped and their boundaries were compared. Then, the numbers of pixels in the interior and exterior of the original feature that is not matched in the segmented feature were counted as the interior and exterior error, respectively. With this, the mean intensity of the segmented feature was also compared with that of the original feature to test the preservation of spectral information between resolution transformations. The results are displayed in Table 3.

In Fig. 5, an example displays a result of feature extraction and mapping for land cover changes. Sample area covers subset of western Australia's Great Victoria Desert which is one of the few remaining habitats

Table 3. Segmentation errors by anisotropic diffusion pyramid.

Root level	Interior error	Exterior error	Total error	Mean intensity of the segmented feature	Intensity error
Level3	98	103	201	201.1	0.8
Level4	102	131	233	205.2	3.3



(a) (b)

Fig. 5. Feature extraction example: (a) 1024x1024 MSS sample which shows fire scars (b) Mapping of fire scars extracted as land cover changes (grayscale levels represent fires occurring in different years).

undisturbed by the human activity. Fig. 5 (a) is the enhanced 1024×1024 subset image which shows fire scars. In Fig. 5 (b), the fire arrival processes during 18 years are mapped using feature extraction system from the Landsat Multispectral Scanner (MSS) imagery of the study area: data were collected for the 12 year period (1972, 1979, 1980~1989).

4. Conclusions

This study focused on investigation of efficient methods for feature extraction system for land cover changes based on multitemporal remotely sensed data; this is accomplished by preprocessing, change detection using image-subtraction, thresholding, and segmentation. The detected change-areas can be extracted as features in final segmentation process. Anisotropic diffusion method was utilized to yield intra-region smoothing such that neighboring smoothing is inhibited at the boundary areas to delineate exact boundaries of features. This Region-based segmentation forms region aggregation of pixel-based differencing results with accurate boundaries. To process a great amount of multitemporal data covering large area, computationally efficient methodology is to be considered in the selection of processing and analysis technique; a multiframe work in pyramid structure was employed in this study.

Remotely sensed imagery are timely and cost-effective data that can be used to monitor land cover change over a long-term period and the proposed approach can provide useful methodology for the study of landscape dynamics. According to the spectral or spatial characteristics in the concerning change such as an urban area change or land cover change as a result of a natural disaster like fire, more efficient and appropriate methodology can be further investigated in each process. For instance, to process and analyze image data including abundant texture characteristics, a region-based approach exploiting spatial adjacency relationships such as MRF can be successively utilized to model texture and region formation in segmentation process (Derin *et al.*, 1984).

References

Acton, S. T., A. C. Bovik, and M. M. Crawford, 1994. Anisotropic diffusion pyramids for image segmentation, *Proc. IEEE International Conference on Image Processing*, Austin, Texas, Nov. 13-16, 3: 478-482.

Burt, P. J., T. Hong, and A. Rosenfeld, 1981. Segmentation and estimation of region properties through coopertative hierarchical computation, *IEEE Trans. on Systems, Man, and Cybernetics*, SMC-11(12): 862-878

Chavez, P. S. Jr., 1988. An Improved Dark-object subtraction technique for atmospheric scattering correction of multispectral data, *Remote Sens. of Environ.* 245: 459-472.

Chavez, P. S. Jr., 1989. Radiometric Calibration of Lansat Thematic Mapper multispectral images, *Photogramm. Eng. Remote Sens.*, 55: 1285-1294.

Chavez, P. S. Jr., 1996. Image-based Atmospheric Corrections revisted and improved, *Photogramm. Eng. Remote Sens.*, 62: 1025-1036.

Derin, H., H. Elliot, R. Cristi, and D. Geman, 1984. Bayes smoothing algorithms for segmentation of binary images modeled by Markov random field, *Proc. IEEE 1984 Int. Conf. ASSP*, San Diego, CA, Mar. 32.6.1-32.6.4.

Kaufman, Y. J., A. E. Wald, L. A. Remer, Bo-Cai Gao, Rong-Rong Li, and L. Flynn, 1997. The MODIS 2.1-μm (m channel-correlation with visible reflectance for use in remote sensing of aerosol, *IEEE Trans. Geosci. Remote Sens.*, 35: 1-13.

Michener, W. K. and P. F. Houhoulis, 1997. Detection of vegetation changes associated with extensive flooding in a forested ecosystem, *Photogramm, Eng. Remote Sens.*, 63: 1363-1374.

Perona, P. and J. Malik, 1990. Scale-space and edge detection using anisotropic diffusion, *IEEE Trans. on Pattern Anal. and Mach. Intell*, PAMI-12 (6):629-639

Rosenfel, A., 1984. Some Useful Properties of Pyramids, *Multiresolution Image Processing and Analysis*, eds., A. Rosenfeld, New York, USA.

Schott, J. R., C. Salvaggio, and W. J. Volchok, 1988. Radiometric scene normalization using pseudoinvariant features, *Remote Sens. Environ.*, 26: 1-16.

Song, C., C. E. Woodcock, K. C. Seto, M. P. Lenney, and S. A. Macomber, 2001. Classification and Change Detection Using Landsat TM data: When and How to Correct Atmospheric Effects?, *Remote Sens. of Environ.*, 75: 230-244.