LAND USE/COVER CHANGE DETECTION BASED ON ARTIFICIAL NEURAL NETWORKS AND WAVELET BASED TEXTURE ANALYSIS

Ping XIAO [a], Xi'an ZHAO [b], Deren LI [c]

[a] Shaanxi Geomatics Center, 710054 Xi'an, China
[b] Xi`an Technical University of Architecture, 710054 Xi'an, China
[c] Wuhan University, 430070, Wuhan, P.R.China

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ABSTRACT:

In the paper, the integration of Artificial Neural Network(ANN)、Wavelets texture analysis and GIS has been introduced to and successfully used in Land use/cover change detection (LUCCD) detection to improve the change detection accuracy and efficiency. The input and output, and the settings of ANN have been studied for the change detection, and different ANN models and algorithms have been introduced to improve the performance of ANN. The results have shown that using ANN for change detection has many advantages over the traditional ones like images difference and post classification, such as being able to provide both changed areas and categories at same time, easy to integrate multi-source data, and free of the problems concerning the threshold determination and the error accumulation.
The texture features of the images, which are calculated from wavelet transform, have been used as additional information in LUCCD to improve the results of gray-level based change detection. The geographic information in GIS has also been used to help automatically select sample points of urban land in the images during ANN training .

1. INTRODUCTION

Land use/cover change detection (LUCCD) from satellite images is an efficient way to get information about environmental change on the Earth and to provide information for updating existed topographic database. There are many peoples who are dealing with such researches and many methods and procedures have been proposed and used in LUCCD as so far, including Post-classification, image difference, changed vector analysis, digitizing from screen, comparison of the image with other data, knowledge-based pattern recognition etc..,. Generally, there are some shortcomings in traditional LUCCD which influence the accuracy of the results.

Firstly, commonly used methods are not perfect. For example, when using image difference in LUCCD, the major problem is difficult determination of the threshold for changed area, and the results of this method can only show changed areas, not changed categories (i. e, what kinds of land covers have changed). So the classifications for those changed areas have to been done in order to get the changed categories; When using Post-classification in LUCCD, the major problems are accumulations of classification errors. The accuracy of automatic classification for each image is not high, so the change detection results from them are even lower.
Secondly, the basic information used to perform LUCCD is not enough, that is , only the image gray value are used as basic information. Some mistakes often happened in the change detection results because of the spectrum similarity among some land covers in satellite images.
In order to overcome the shortcomings mentioned above, this paper have made following improvements in LUCCD:

1. ANN based methods have been used in LUCCD. ANNs have strong abilities of non-linear mapping, good self-adaptability and low demand for data distribution, and thus have much more advantages over statistics-based methods in image processing.
2. The texture features have also been used as important additional information in LUCCD so that the gray-based change detection results can be improved.
3. Wavelet transformations have been used as a basis for the texture measures because of their characteristics of multi resolutions and multi directions in texture analysis.

2. PREPARING FOR LUCCD

2.1 Experimental Data

The test area is in local area of Guangdong province. The experimental data include satellite images of TM and Spot at two dates, and the 1:50000 topographic data. The detail information about them has been shown in table 3.1. The images have been shown in figure 1(see picture plate)

2.2 Geometric and Spectral Correction for the Images

The geometric correction and radiation correction have been made before performing the change detection. The geometric corrections have been made using Erdas software by selecting control points on the topographic map and corresponding points on the images. Spectral corrections have been made using statistical regressions.

Region	Data	Size (pixels)	Roles in LUCCD
Zhuhai	TM(1992,8) TM(1996,7)	327*411	for change detection
	Spot (1995,6)	840*840	selecting sample data and testifying the results
	1:50000 DLG		selecting sample data of "urban areas "

Table 1. Experimental data

2.3 Determination of the Categories for Changed Land Covers

Before the change detection, we should make a determination for the land use/cover change, that is , to determine how many kinds of land covers have changed and what changes have happened. For simple reason, the standards have been made according to the practical situation in local area so that the number of the changed categories can be reduced greatly.
The land use/covers in test area include： Class1: urban area; Class2： water（river/pond/sea）; Class3： agriculture area; Class4：nuked land ; Class5： forest ;

According to the practical investigation, the major trends of land use/cover change in test area are from cultivated land to nuked land and nuked land to urban land, which lead to the reduction of cultivated land and sprawling of urban area.
The categories for the land use/ cover change in test area have been shown in table 2:

	Class1	Class2	Class3	Class4	Class5
Class1	1				
Class2		2		3	
Class3	4	5	6	7	
Class4	8			9	
Class5			10	10	11

Table 2. the categories of land use/ cover change in test area

In table 2，there are 11 categories , among which changes "from forest to nuked land " and "from forest to agriculture land " have been put into one category. Each code in the table represents certain kind of change. For example, "4" represents the change of "agriculture to urban land".

3. THE CHANGE DETECTION USING ANN

The general workflows for LUCCD using ANN include the image preprocessing(geometric and spectral correction), and ANN-based change detection.

3.1 The Network Model

In the experiment, two kinds of ANN models have been used. One is BPNN (Back Propagation Neural Network)，the other is LVQ(Learning Vector Quantization). For BPNN, many experiments have been done in order to find the best framework, and the results have shown that the four- layer network is the best, which has been shown in figure 2.

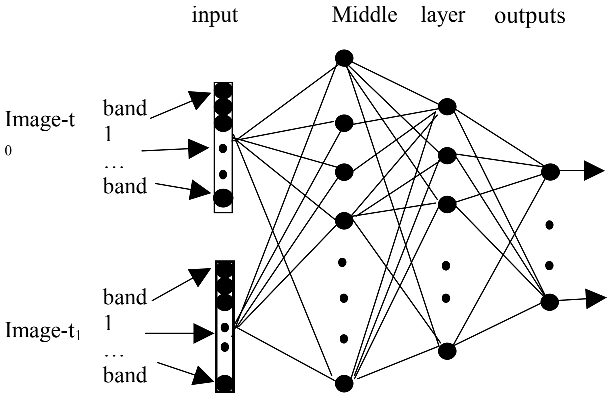


Figure 2. Change detection graph based on 4 -layer BPNN

For LVQ, the network structures for the change detection are almost the same as BPNN, the only difference is in the principles of two network models. Unlike BPNN，LVQ performs data trainings based on competitive rules. The input vectors in LVQ have been classified in competitive layers. If two input vectors have smallest distance, they have been put into one category. If an input vector is nearest to some object vector, it should be put into same category with the object vector.

The settings of BPNN and LVQ have been shown in the table3.

	settings	Training time	Images
BPNN	6-30-30-11	4 minutes	TM - 5、4、3 （1992）
LVQ	6-25-11-11	2 minutes	TM - 5、4、3 （1996）

Table 3. Network Settings of BPNN and LVQ

Unlike the image classification using ANN, when performing LUCCD using ANN, the input nodes of the networks are the image pixel values of two dates in certain order (band3,4 and 5 have been used in the experiment ,so the number of the input nodes is 6), and the outputs contain both the classification information of each date and the change information of two dates, For example, ［0 0 0 0 0 0 0 0 0 0 1］ meaning the change from "agriculture land " to "urban land" (there are 11 change categories, so the number of output nodes is 11).
Concerning the local context of the images, the average gray values of 5*5 windows in the images have been used as inputs of the networks.

3.2 ANN Training and Simulation

The existed 1:50000 topographic data in the database has been used to select sample data about urban areas for ANN training, and Spot image has been used to select sample data about other areas. After 30000 circulations in ANN training, it took 4 minutes for BPNN to reach convergence, and 2 minutes for LVQ(after 13000 circulations). When finishing the network training, the corresponding pixel values of the two TM images in different bands have been input into the trained network, and the change results can be got from the network outputs, which have been shown in fig. 3-b and fig.3-c (see picture plate).

3.3 Comparison and Analysis of the Results

For the comparison and the analysis ，besides the ANN post-classification, the post-classification has also been used in the LUCCD experiment. In post-classification for LUCCD, firstly the supervised classifications have been made on the preprocessed images of the two dates, and then the change results can be got by comparing each pixels on the classified images of two dates. The results have been shown in fig.4-a (see picture plate)。 The accuracy evaluations for post-classification, BPNN and LVQ have been made in table 4.

Methods	Total accuracy	Kappa
post-classification	82.09%	0.8063
BPNN	87.27%	0.8609
LVQ	88.09%	0.8683

Table 4. Accuracy comparison of several methods

From the change detection results based on different methods, the following conclusion could been reached:
Firstly, using ANN for LUCCD is practical and efficient, and the result accuracy is better than post-classification. The procedures for change detection using ANN are also simpler than post-classification because the ANN outputs contain the information both for classification and for the land cover change.

Secondly，the ANN based change detection can easily integrate multi-source data . If some additional information need to join in the change detection, the only way you need to do is to put the additional information into the input of the networks in some orders.

Thirdly, the change detections using LVQ have more efficient than using BPNN, although the accuracy is almost same, because the network convergence speed for LVQ is faster than BPNN, and LVQ is not easy to reach the local minimum.
Finally，there have been still some errors in the change detection results even for ANN based methods, because only gray-level information in the images has been used for the change detection . The ANN methods can reduce the errors, but can not eliminate them. The reasons why the errors exist in the results is that there are similarities between the spectrums for agriculture and urban land. Therefore. the texture information should also be introduced in the change detection.

4. LUCCD CONCERNING WAVELET-BASED IMAGE TEXTURE

The image texture features contain the information about spatial distribution of iamge pixels. There are many methods proposed for the calculation of the texture features, including Gray Level Statistics , Laws Masks , Fourier Transform Methods etc.. the common shortcoming of which is that the motheds can not analize the signals both in spatial and frequence domians at same time.

4.1 The Wavelet besed Texture Features

when used as a foundation for a texture measure the wavelet transform enjoys a number of advantages over other methods. One is Spatial discrimination, that is , the wavelet transform is localised in the spatial and frequency domians. Second is Multi-scale representation, that is , the scaling parameters of the wavelet transform can be varied to represent data at the most appropriate scale.

In general, the wavelet transform itself is not used as the feature processing. Instead it is typical for either squaring or full-wave rectification to be used to give the characteristic feature.

4.1.1 Gray-level Features

To obtain features which reflect scale-dependent properties, a gray-level feature is extracted from each scale separately. An appropriate quantity is the energy, shown in equation (1).

$$E_j^i = \frac{1}{MN}\sum_{m=1}^{M}\sum_{n=1}^{N}(D_j^i(m,n))^2 \quad (1)$$

where **M , N** =the size of given scope
$D_j^i(m,n)$ = the element of sub-images from wavelet transform
j = the direction of wavelet transform
i = the depth of wavelet transform

These wavelet energy signatures E_j^i reflect the distribution of energy along the frequency axis over scale and orientation.

4.1.2 Colour Features

For image analysis, color and texture are two of the most important propertirs, especially when one is dealing with real world images. Classical image analysis schemes only take into account the pixel gray-levals, which represents the total amount of visibale light at the pixels position.The performance of such schemes can be improved by adding color information. the color of a pixel is typically represented with the RGB tristimulus values.Wavelet texture analysis can be extended to colour texture. Colour images are typically represented by RGB tristimulus values which correspond to three colour bands. The most traightforward extension of the wavelet energy signatures to colour images is to transform each colour plane separately: i.e. replace D by R, G, and B-plane consecutively in equation (1).

Therefore, for a same image, the dimension of its color features is three times of its gray-level features.

4.2 Change Detection Concerning the Texture Information

In order to use both pixel gray value and texture feature in LUCCD, a reasonable procedure should be proposed. As shown in the figure 4, LUCCD has first been performed using ANN, and produced the change detection results , we called them preliminary results. Then the preliminary results have been improved by texture feature information.

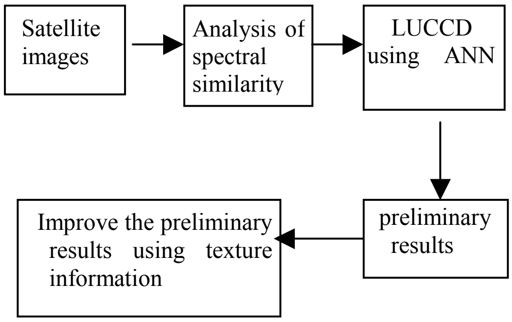


Figure 4. Change detection based on ANN and Wavelet based texture features

4.2.1 Analysis of Spectral Similarity

The purpose for the analysis of spectral similarity is to find those land covers similar in spectrum, so that the correction could be made using texture information. In the experiment, the histogram comparison has been used for the purpose. Through the comparison, the "urban land" and "agriculture land " have been found to be similar in spectrum.

According to the analysis in the experiment, it has been found that in the preliminary results the change categories containing "agriculture land" and "urban land " should been determined further.

4.2.2 Improve the Results Using Wavelet-based Texture features

In the experiment, one-order Lemarié-Battle has been used to make wavelet transform, during which the tree-structured decomposition has been used. The RGB color texture features have been calculated .

The process for improving the preliminary results by texture information actually is a texture classification. The work space are not the whole images, but those pixels in which the change results need to improve. LVQ has been used to make texture classification in original image pixels corresponding those in the preliminary results needed to improve. Unlike gray-level classification using ANN, the inputs of the networks for texture classification are features which have been calculated before. According to the results of texture classification, the final change results can be reached.

For example, if a pixel on the preliminary results represents the change of "agriculture – nuked land ", "agriculture land" in 1992 satellite image should be chosen to perform the texture classification because its spectrum is similar with ""urban land ", and if the outputs of texture classification for "agriculture land" is "urban land ", the preliminary results should be changed from "agriculture – nuked land" to "urban – nuked land".

The final results of change detection have been shown in fig. 3-d （see picture plate）, from which we can find that some errors in gray-based change detection have been removed.

	General accuracy	Kappa
LUCCD based on pixel gray values （BPNN）	87.27%	0.8609
Improved results by texture information	91.64 %	0.9039

Table 5. The accuracy comparison of LUCCD

For evaluation of the accuracy, 200 sample points have been chosen to calculate the general accuracy and Kappa value , and the results have been sown in table 5.

From the results , it has been found that the wavelet-based texture information can be used in the change detection to correct the misclassification between the "agriculture land" and "urban land", so that the accuracy of final results can reach 91% above.

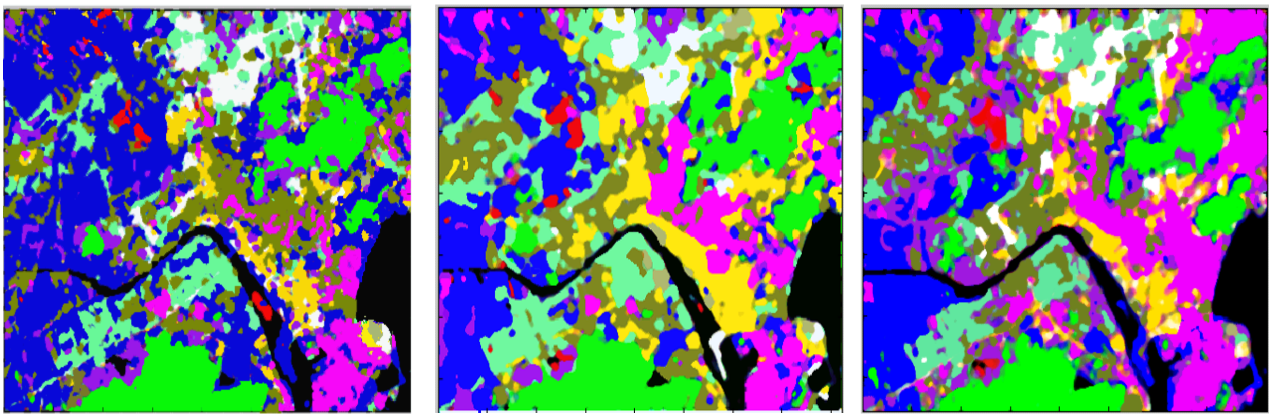
5. CONCLUSION

ANN has strong ability of self -organizing and self-learning, and wavelet theory can be used to efficiently represent the image texture features. In land use/cover change detection, reasonable use of both techniques can make up with the shortcomings of traditional methods, and thus enhance the change detection efficiency and accuracy.

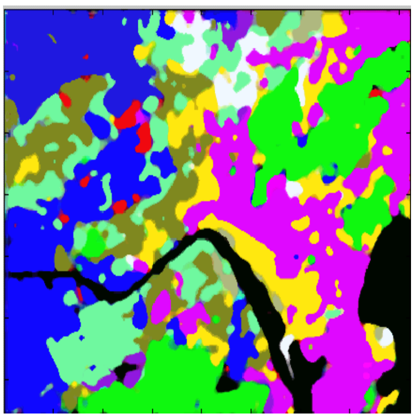
5.1 LUCCD Based on ANN and Wavelet based Texture Analysis picture plate

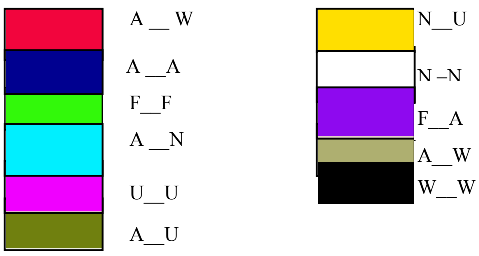
a）: TM543 in 1992 　　 b）: TM543 in 1996 　　 c): TM and topographic data

Figure 1. TM images of different times and the overlay with geographic data



a） Post classification 　　 b） BPNN 　　 c) LVQ





A: agriculture; F: forest; N: nuked land; U: urban land; W: water;

d）improved results from texture information

Figure 3. Change detection results from different methods

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