Automatic Detection Technique of Residential Area Change Based on Topological Analysis

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ABSTRACT:

Based on topological analysis, an automatic detection method of residential area change is presented in this paper. Firstly, we demonstrated the importance of extracting residential area in remote sensing images accurately and automatically. Then, it is found that the old vector of the same region even at different time is useful to obtain the train samples. By applying old vector, we classified the remote sensing image, and extracted the residential area automatically. Consequently, topological analysis is applied to detect six different types of change automatically. Experimental results of residential areas detection on SPOT images show the merit and accuracy of the proposed method.

1. INTRODUCTION

The residential area changes very fast during the development of city. The detection of spatial distribution and change models of residential areas is a kind of fundamental work in the fields of urban mapping and monitoring.

Many methods of residential extraction and change detection have been proposed. Andrea provided a comparison of two different classification schemes, one makes use of a modified region-growing technique, and the other measures textural characteristics by means of the co-occurrence matrix.Yang developed a method of extracting residential area from remote sensing images based on spectrum feature of TM images. Yiyi obtained training samples manually and then extracted residential area from aerial photography using region-growing technique. For the reflectance of residential area is complex, the existing methods to detect the changes of residential usually need lots of manual interference, which can not meet the needs of practice work. All the approaches have shortages as following: (1) The threshold of extraction is given empirically. (2) Only a few change types of residential areas can be detected automatically by the way of simply adding the extracted residential area onto the old vector map, which is impossible to distinguish vanished area from vanished part of combined change area and new area from new part of combined change area.

In this paper, the information of old vector is utilized to solve the problem of threshold determination in residential extraction. Based on the result of extraction, we can detect 6 mainly change types of residential areas, such as vanished, new, outstretched, retreated, partly vanished and partly outstretched (combined change), unchanged automatically by analyzing the topological relationship of residential area in recent image and old vector map. The process of detection is described in figure1.

Experimental results of residential areas detection on panchromatic remote sensing images are presented to show the feasibility of the proposed method.

This paper is organized as follow. In Section2, the extraction algorithm applied in this paper is introduced. Then, topological analysis of residential areas in recent images and old vector map is discussed in Section3. The experimental results of the proposed method are given in Section4. Finally, we conclude this paper in Section5.

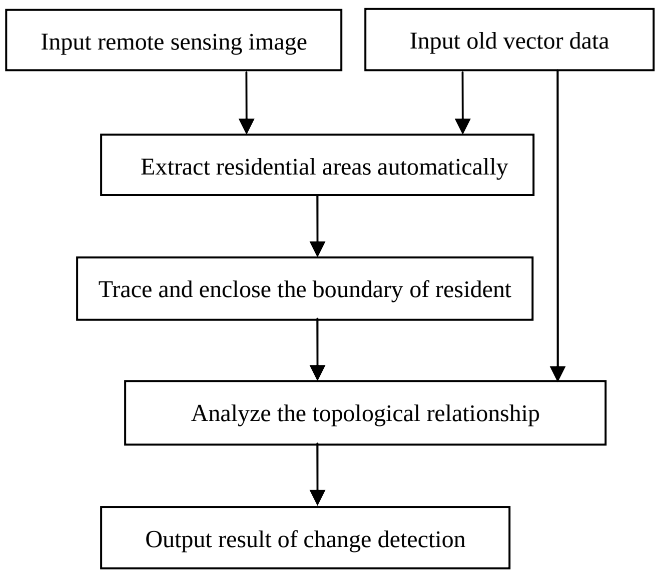

Figure1: The process of the automatic Detection of Residential Area

2. RESIDENTIAL AREA EXTRACTION

To compare residential areas on recent images with a standard vector map, the first step is to extract residential areas fast and accurately. The accuracy of extraction directly affects the correction of change detection.

a) Analysis of Residential Area's Characteristic

In order to extract residential areas from remote sensing images, it is necessary to choose some characteristics which are able to distinguish the residential areas from other areas correctly and effectively. In a segmentation algorithm based on LAW, energy feature of each pixel is computed as its characteristic in classification. Because it is easy to identify residential areas in the characteristic space, the optimum three templates of LAW have been used to compute energy feature of pixels in SPOT images in the paper, which are showed as following.

$$\begin{bmatrix} -1 & -4 & -6 & -4 & -1 \\ -2 & -8 & -12 & -8 & -2 \\ 0 & 0 & 0 & 0 & 0 \\ 2 & 8 & 12 & 8 & 2 \\ 1 & 4 & 6 & 4 & 1 \end{bmatrix}$$

$$\begin{bmatrix} -1 & 0 & 2 & 0 & -1 \\ -2 & 0 & 4 & 0 & -2 \\ 0 & 0 & 0 & 0 & 0 \\ 2 & 0 & -4 & 0 & 2 \\ 1 & 0 & -2 & 0 & 1 \end{bmatrix} \begin{bmatrix} -1 & 0 & 2 & 0 & -1 \\ -4 & 0 & 8 & 0 & -4 \\ -6 & 0 & 12 & 0 & -6 \\ -4 & 0 & 8 & 0 & -4 \\ -1 & 0 & 2 & 0 & -1 \end{bmatrix}$$

Figure2: Three templates of LAW applied in the extraction algorithm

b) Extraction of Residential Areas Based on Old Vector Data

The paper proposed a new method by using old vector data of the same place, which can make it possible to obtain training sample without manual interference. By this way, the process of image recognition is translated into the process of comparison. The method of extraction includes two steps. In the first step, information of old vector is utilized to obtain training sample of remote sensing image, so that the problem of threshold determination in residential extraction is solved. The second step is to test unknown parts of images according to the threshold. The algorithm works in the following way:

Step1: Training samples
Computation of the convolution is done by means of the operator:

$$F(i,j) = A(i,j) \times I(i,j) = \sum_{s=0}^{N-1} \sum_{p=0}^{N-1} A(k,l) I(k+i, l+j)$$

Where A(i,j) and I(i,j) represent, respectively, the template mentioned above and the gray level of the pixel whose coordinate is (i,j) in training samples.

After this operation, a subwindow is set up. Each pixel is substituted by the mean value of the subwindow as follow:

$$TE(i,j) = \frac{i}{(2n+1)^2} \sum_{k=i-n}^{i+n} \sum_{l=j-n}^{j+n} F(k,l)$$

Where n is the dimension of subwindow. TE(i,j) is computed as the energy characteristic for the pixel(i,j).

Calculate the training region histogram based on its energy characteristic. The peak of the histogram is chosen to be the threshold for classification in Step2.

Step2: Testing unknown parts

For each pixel of testing image, energy characteristic is calculated using the same procedure as Step1. The original image is segmented by the threshold. Pixels whose energy characteristics are higher than the threshold are labeled residential area.

c) Trace and Enclose the Boundary of Resident

In order to analyze topological relations between extracted residential area and old vector map, the region extracted from recent remote sensing images must be enclosed and the boundary of which must be accurate. Edge tracing and enclosing algorithm is applied on request.

3. CHANGE DETECTION BASED ON TOPOLOGICAL ANALYSIS

After the images are segmented and labels are assigned to all regions, the next step is change detection. For comparison residential areas from recent remote sensing image with old vector thematic map, six forms of change are considered, including vanished, new, outstretched, retreated, partly vanished and partly outstretched (combined change) and unchanged. In the method proposed in this paper, topological analysis is applied to identify spatial relationship of extracted residential area and old vector area automatically. Six different forms of change are able to be detected easily.

a) Topological Analysis of Extracted Regions and Old Vector Regions

There are two main models of spatial topological relation: intersection model based on point-set topology and RCC (Region Connect Calculus) model based on logical calculus. Intersection model include 4-intersection and 9-intersection model. The extracted residential area and vector areas are represented as regions. Because 4-intersection and 9-intersection have the same distinguishable possibility in topological relation between regions, however, 4-inersection is much easily to perform, so 4-intersection model is applied in the method.

In the 4-intersetion model, each object is considered as a set of point, so that each object can be divided into edge and inner.

For spatial objects A and B, ∂A and A^0 represent, respectively, the edge and inner of A, ∂B and B^0 represent the edge and inner of B. A matrix composed by the relationship between them is shown as follow:

$$R(A,B)=\begin{bmatrix} A^0\cap B^0 & A^0\cap\partial B \\ \partial A\cap B^0 & \partial A\cap\partial B \end{bmatrix}$$

Each member of the matrix has 2 different value ($\neg\varnothing$ and $\varnothing$). After insignificant relationships being removed, eight topological relations of regions are able to be distinguished, such as separation, anastomosis, intersection, covered, included, equality, coverage and inclusion. The extracted residential regions are defined as G ($G1,G2...Gm$) and old vector regions are defined as V ($V1,V2...Vn$), where m and n represent the number of residential regions. We use the topological relations discussed above to describe the change forms as follow:

A) If $R(Vi,Gj)=\begin{bmatrix} \varnothing & \varnothing \\ \varnothing & \varnothing \end{bmatrix}$,Gj∈G, j=1,…,m, Vi separates from every region in extracted image, that is, Vi is vanished residential region.

B) If $R(Gi,Vj)=\begin{bmatrix} \varnothing & \varnothing \\ \varnothing & \varnothing \end{bmatrix}$, Vj∈V, j=1,…,n, Gi separates from every region in old vector map, that is, Gi is new residential region.

C) If $R(Gi,Vj)=\begin{bmatrix} \neg\varnothing & \neg\varnothing \\ \varnothing & \varnothing \end{bmatrix}$,

or $R(Gi,Vj)=\begin{bmatrix} \neg\varnothing & \neg\varnothing \\ \varnothing & \neg\varnothing \end{bmatrix}$, Gi includes Vi, or Gi covers Vi, that is, Gi is outstretched residential region.

D) If $R(Gi,Vj)=\begin{bmatrix} \neg\varnothing & \varnothing \\ \neg\varnothing & \varnothing \end{bmatrix}$,or

$R(Gi,Vj)=\begin{bmatrix} \neg\varnothing & \varnothing \\ \neg\varnothing & \neg\varnothing \end{bmatrix}$, Gi is included by Vi, or Gi is covered by Vi, that is Gi is retreated residential region.

E) If $R(Gi,Vj)=\begin{bmatrix} \neg\varnothing & \neg\varnothing \\ \neg\varnothing & \neg\varnothing \end{bmatrix}$,or

$R(Gi,Vj)=\begin{bmatrix} \varnothing & \varnothing \\ \varnothing & \neg\varnothing \end{bmatrix}$,Gi intersects with Vi, or Gi anastomoses with Vi, that is, part of Gi is new , part of Gi is vanished. We define this form as combined change.

F) If $R(Gi,Vj)=\begin{bmatrix} \neg\varnothing & \varnothing \\ \varnothing & \neg\varnothing \end{bmatrix}$,Gi is equal to Vi, that is, Gi is unchanged residential region.

b) Change Detection Based on Topological Analysis

The topological relationship of a region pair discussed above can be used to detect change forms. The process to detect change forms automatically is as follows:

a) Code the extraction of residential areas and old vector areas respectively, so that the edge and inner of residential areas are given different code. For example, we can give the edge of the region in extracted image code 1, the inner of the same region code 3, at the same time, we give the edge of the region in old vector map code 3, the inner of the same region code 4

b) Calculate the matrix $R(Gi,Vj)$ based on a region Gi in extracted images and each region Vj ($\{\forall Vj \mid Vj\in V\}$) in old vector map. After compare the result with B) to F) discussed in 1), we can confirm the change form of Gi.

c) Calculate the matrix $R(Vi,Gj)$ based on a region Vi in old vector map and each region Gj ($\{\forall Gj \mid Gj\in G\}$) in extracted images. After compare the result with A), we can confirm the change form of Vi.

4. EXPERIMENTAL RESULTS

The method proposed in the paper has be applied to detect several SPOT images, whose resolution is 10m. The image (a) and image (b) in Figure 3 are SPOT images of different areas. Vector data is added onto images as shown in image (b) and image (j), which is expressed in red. Five different forms of change are all included.

Image (c) shows the extracted result from image (a) using LAW's energy templates. Boundaries are traced and enclosed based on the extract result, which are shown in image (d) and image (k). The rate of correct results for two images is over

85%, without any manual interference.

From image(e) to image(l), five forms of change are detected and expressed in different colors. Image(e) shows the vanished regions in green; image(f) shows the new regions in red; image(g) shows the outstretched regions, where unchanged area is expressed in grey and outstretched area is expressed in pink; image(h) shows the combine changed regions, where unchanged area is expressed in lilac, outstretched area is expressed in modena and retreated area is expressed in blue; image(i) shows the retreated regions, where the area extracted from recent remote sensing image is expressed in yellow and retreated area relative to old vector data is expressed in green.

Because of the complexity of reality, it is hard to find regions completely unchanged in remote sensing images. To confirm the completeness of our algorithm, unchanged is also presented as a change form and discussed.

The Experimental results above illustrate the merit and feasibility of the proposed method. It should be efficient for data update, and can improve the degree of automation in modification of map greatly.

5. CONCLUSIONS

Composed by constructions, roads, green land, and other types of objects, the residential area is very complicate. The existing methods to detect the change of residential usually have two shortages: (1) The threshold of extraction is given empirically. Lots of manual interference is needed, which can not meet the needs of practice work.(2)Only a few change types of residential areas can be detected automatically by the way of simply add the extracted residential area onto the old vector map.

In this paper, the information of old vector is utilized to solve the problem of threshold determination. After extracting residential area from remote sensing image, we analyze the topological relationship between extracted results and old vector map to detect change forms automatically. The experimental results show the accuracy and feasibility of our algorithm.

There are two problems to be solved in the future.

(1) To improve the accuracy of our algorithm, extraction technique should be developed.

(2) Our algorithm should be extended to multispectral remote sensing images.

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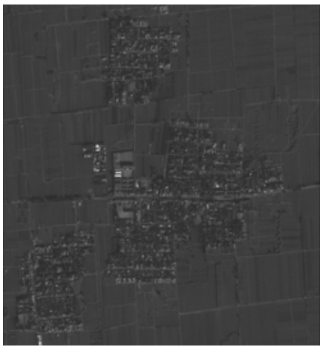
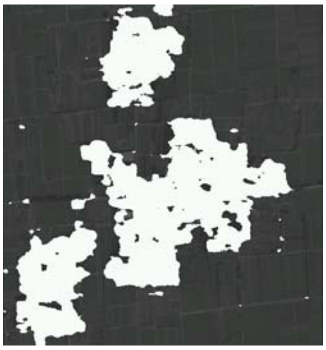
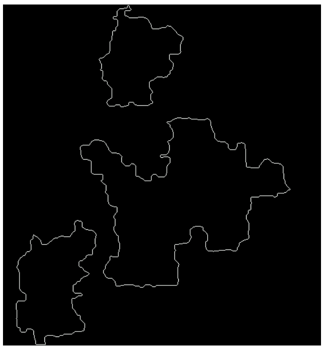


(a) SPOT5 image

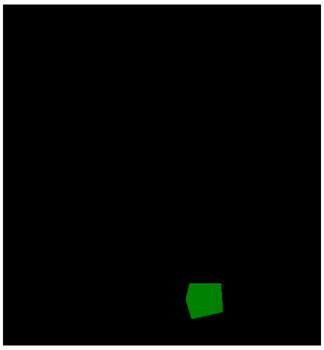
(b) vector added to image



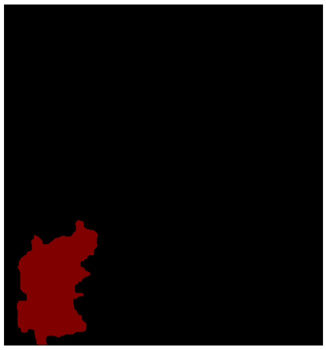
(c) extracted result



(d) edge tracing and enclosing

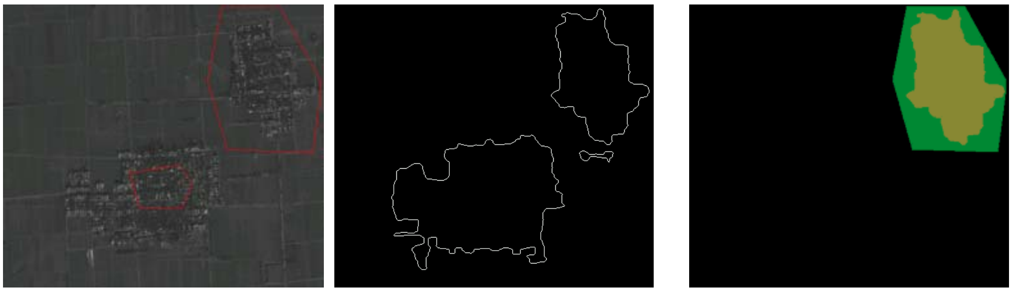


(e) vanished residential



(f) new residential region
result region

(g) outstretched residential region (h) combine changed residential region (i) SPOT5 image



(j) vector added to image (k) edge tracing and enclosing result (l) retreated residential region

Figure 3 Experimental results

REFERENCES

Adrea Baraldi, Flavio Parmiggiani, Urban Area Classification by Multispectral SPOT Images, IEEE Transactions on Geoscience and Remote Sensing, VOL.28, NO.4, JULY 1990

Guo Qingsheng, Cai Yongxiang, Du Xiaochu, Wang Lehui, Equivalent Transformation of Basic Topological Relations Between a Line and Region During Abstraction Process. Geomatics and Information Science of Wuhan University, 2006(8)

Pan Li, Zhang Zhihua, Zhang Jianqing, Residential Areas Recognition by Fusing Region Data and Edge Features. Geomatics and Information Science of Wuhan University, 2006(8)

Selim Aksoy, Krzysztof Koperski, Carsten Tusk, Giovanni Marchisio, James C. Tilton, Learning Bayesian Classifiers for Scene Classification With a Visual Grammar,IEEE Ttransactions on geoscience and remote sensing,VOL 43,NO 3,match 2005

Selim Aksoy, Krzysztof Koperski, Carsten Tusk, Giovanni Marchisio, Learning Bayesian Classifiers for a Visual Grammer, IEEE GRSS Workshop on Advances in Techniques for Analysis of Remotely Sensed Data, Washington DC, Oct.2003,pp.212-218

Su Junying, Cao Hui, Zhang Jianqing, Semi-automatic Extraction Technique of Residential Area in High Resolution Remote Sensing Image. Geomatics and Information Science of Wuhan University, 2004(9)

Yang Cunjian, Zhou Chenghu, Extraction Residential Areas on the TM Imagery, JOURNAL OF REMOTE SENSING, 2000,5(4)

Zhai Huiqin, Wang Mingxiao, Semi-Automatic Habitation Collection in Aerial Image. Theory Research, 2005（4）,13-15