

FAST RESIDENTIAL AREA EXTRACTION ALGORITHM IN HIGH RESOLUTION REMOTE SENSING IMAGE BASED ON TEXTURE ANALYSIS

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ABSTRACT:

In this paper a residential area texture description based on the 3×3 region grey deviations is proposed which is much better than based on the grey symbiotic matrix and Fourier power spectrum through the experiment and comparison data. Considering the original residential area in the image is composed by the mixed pixels, which have interlaced bright and dark pixels and the darkness area is very similar to the background, the texture character image is solved with the original image at first and a transformation processing of the texture character image such as the Gauss blur is applied to make the residential area in the texture character image possess accordant grey value and definite contrast relative to the background area so that the segmentation threshold can be easy to obtain through the histogram processing or iterate processing in the texture character image. Some residential areas with large interior texture change and asymmetric texture representation in the original image have the same case in the deviation image while they can be changed from the asymmetric region into equality region through the transformation processing to the texture character image for the successful segmentation. And a skeleton processing is proposed to eliminate the road from the residential area. The experiment results of the semi-automatic extraction of the residential area in the remote sensing image with 3 meters ground resolution show this technique is very simple and effective to the semi-automatic extraction of the residential area and can meet the precision requirement of the mapping and surveying with satellite images.

1. INTRODUCTION

High-resolution sensor technique has made great progress since 1990's. The resolution of some Multi-spectrum remote sensing images has reached 4 meters and that of some single spectrum has been within 1 meter. High-resolution image can show the object information such as structure, texture and detail clearly, which make it possible that observing object detail changes on the earth through less space scale, large scale remote sensing mapping and supervising the affection of human activity on our environment. It's very important for the human residential area planning and decision-making in economic region planning. A residential area is a space entity composed of buildings, roads between buildings, green areas, activity areas and production areas, which has its definite structure, function and space shape. Therefore, mastering the space distribution information of a region's residential area will contribute to upholding administration and application departments to make effective decisions. For example, providing disaster estimation department with space distribute information, helping to understand human and region relation, serving for society, economy and arts, upholding the supervision for living area condition and the construction of living environment, processing large scope semi-automatic or automatic mapping with satellite image etc.

The researches of object automatic detection and recognition (Zhang, 1996) are focused on the linearity object such as road, river, electric power line and waters pound pipes for the linearity object is the simpler object in the geometric objects. The extraction of linearity objects can be realized through image strengthen, slender and track processing. The extraction technique of the difficult geometric shape object such as the residential area has two ways: automatic extraction and semi-automatic extraction. Texture feature is the direct embodiment of the object structure and space arrangement in the image. Some researches are focused on the residential area extraction of the satellite images while the precision is greatly depended on the image quality and cannot reach the application requirements. Yang, 2001 study to extract and recognize the residential area with its spectrum character and space

distribution knowledge to TM images while the precision can just reach 85%. The research based on the nerve network (NN) and the maximum similarity method can reach the precision level of 69.1% and 52.3%. Computer based residential area extraction includes two parts: recognition and measure. Recognition can be easily realized for human but difficult to the computer while in the contrast measure is easy for the computer. The semi-extraction and recognition with human and computer becomes the main study direction (Rob J.Dekker, 2001; V.Bessettes, 1995).

In this paper a residential area texture description based on the 3×3 region grey deviations is proposed which is much better than based on the grey symbiotic matrix and Fourier power spectrum through the experiment and comparison data. Considering the original residential area in the image is composed by the mixed pixels, which have interlaced bright and dark pixels and the darkness area is very similar to the background, the texture character image is solved with the original image at first and a transformation processing of the texture character image such as the Gauss blur is applied to make the residential area in the texture character image possess accordant grey value and definite contrast relative to the background area so that the segmentation threshold can be easy to obtain through the histogram processing or iterate processing in the texture character image. Some residential areas with large interior texture change and asymmetric texture representation in the original image have the same case in the deviation image while they can be changed from the asymmetric region into equality region through the transformation processing to the texture character image for the successful segmentation. And a skeleton processing is proposed to eliminate the road from the residential area. The experiment results of the semi-automatic extraction of the residential area in the remote sensing image with 3 meters ground resolution show this technique is very simple and effective to the semi-automatic extraction of the residential area and can meet the precision requirement of the mapping and surveying with satellite images.

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2. METHODOLOGY

2.1 Residential area image in high-resolution image

Residential area is a spatial entity consists of buildings, road inside the buildings, green ground, activity place and factory and it has some structure, function and spatial state. There are two different kinds of residential area: urban residential area and country residential area. The urban residential area mainly includes buildings, road network, green and vacant ground. The country residential area mainly includes buildings, green and vacant ground, just big country residential area has street. And the density and size of buildings is smaller than the urban residential area. In the high-resolution image, the buildings in the residential area are mixed up a single or cluster light pixels and a few dark pixels. Objects such as the roads, ditch, dykes, dunes and wet ground along the river and lake in the residential area also are light pixels while the water body, vegetation and nudity ground are dark pixels. The residential area belongs to the area object with complex structure and there are some difficulties to describe the residential area image feature through the texture analytical method. The texture character of different residential area has great difference with the change of background and it's very difficult to obtain the self-adaptive segmentation threshold of the residential area and background. And the interior composing of the residential area is very complex and the texture character changes are huge for example the urban residential area may include wide range virescence square with extrusive feature but obvious difference of the background structure which make it very difficult to extract the residential area through one time region increasing. In the other side, the texture characters of road and residential area in the image are quite similar and promiscuous thus it's very difficult to distinguish the road and residential area efficiently. Another difficulty is that the change of the residential area boundary is not obvious and quite similar to the background, which directly affects the precision of residential area extraction. The difference of maximize and minimize grey value is large and the grey distribution range is overlapped to the other object in the high-resolution image. In summary, most of residential area pixels are mixed pixels and less are pure pixels, as Figure 1 shown.



Fig 1(a)

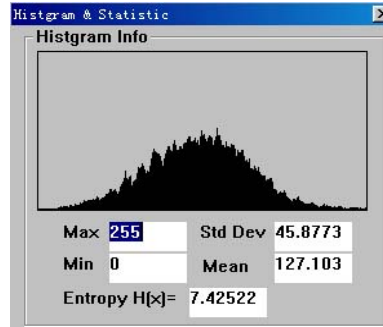


Fig 1(b)

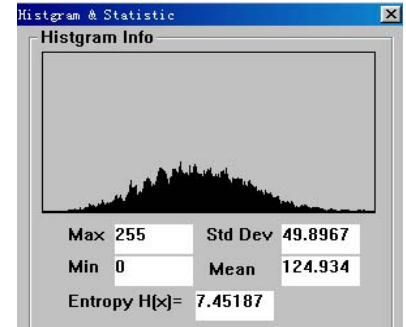


Fig 1(c)

Fig 1 Character Analyze of Resident Area in High Resolution Image

Figure 1(b) and 1(c) are the histogram of the original image and residential image selected from the test image manually. They have the similar distribution. And the statistic values are almost the same(the difference of average is 2.169, the difference of deviation is 4.02 and the difference of entropy is only 0.026). It is very difficult to extract residential area from the test image based on histogram feature in spatial domain. Thus, the automatic extraction of the residential area has many difficulties related to the current research progress in this field.

2.2 Texture Feature Analysis of Residential Images

For the image segmentation based on texture analysis, the selected texture feature should make some image statistic values such as deviation change obviously after the image texture transformation. There are some classic texture feature description methods such as the deviation texture analysis, Fourier texture description and grey symbiotic matrix feature analysis as equation (1), (2) and (3).

$$v_g(i, j) = \frac{1}{W^2} \sum_{k=-w/2}^{w/2} \sum_{l=-w/2}^{w/2} [g(i+k, j+l) - m_g(i, j)]^2 \quad (1)$$

$$m_g(i, j) = \frac{1}{W^2} \sum_{k=-w/2}^{w/2} \sum_{l=-w/2}^{w/2} g(i+k, j+l) \quad (2)$$

Where $v_g(i, j)$ is the deviation feature of pixel (i, j) , and the grey value of pixel (i, j) is $g(i, j)$. The calculation window is $W \times W$ and m_g is the average grey value of the calculation window.

$$P(u, v) = |F(u, v)|^2 \quad (3)$$

$$p(r) = 2 \sum_{\theta=0}^{\pi} P(r, \theta) \quad (4)$$

Where $p(r)$ is the sum of energy in the loop region in the Fourier frequency domain and can be taken as the Fourier texture feature and $F(u, v)$ is the Fourier transformation of image $f(i, j)$.

$$W_M = \sum_i \sum_j P^2(i, j) \quad (5)$$

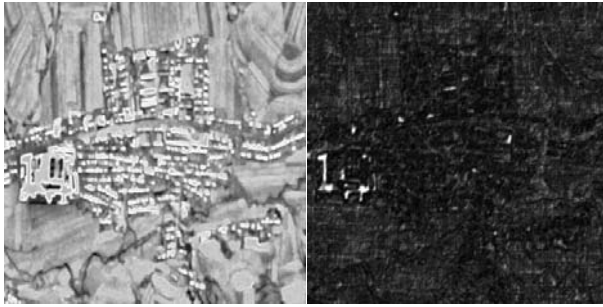
W_M is the grey symbiotic matrix feature and $P(i, j)$ is the grey symbiotic matrix.

Figure 2 shows the high-resolution original image with residential area and corresponding deviation, Fourier and grey symbiotic matrix texture feature images.



2a Original Image

2b Deviation Texture Image



2c Fourier Texture Image 2d Symbiotic Texture Image
Fig 2 Comparison of Texture Feature Image

As figure 2 shown, the deviation feature image has high contrast between the residential area and the other image object while the Fourier texture image is simulate to the original image with low contrast between the residential area and the other image object area. The grey symbiotic matrix texture feature image has little effect to the original image for the grey symbiotic matrix texture feature has strong rule and spatial distribution requirement while most of the original image pixels are mixed pixels, which affect feature spatial distribution rule. Form the above view effect of the texture images, the deviation texture feature analysis has better effect after feature transformation and the Fourier texture image has not obvious effect while the grey symbiotic matrix texture feature analysis has the worse effect.

In order to prove the above view effect to the texture analysis result of different kind of texture feature images, the statistic data of the above images and the residential region image manually selected from the total images are calculated for the comparison of different texture results of contrast and some other statistic value variation, which can make the image segment easier. The statistic data such as the grey average, deviation, maximize and minimize gray value and entropy are calculated in different texture feature dimension, as Table 1 shown:

Table 1 Comparison of the statistic data in the original image and different texture feature images

Feature Value		Max	Min	Dev	Aver	Entropy	Dif. Of Dev	Dif. Of Aver	Dif. Of Entropy
Original Image	Total Area	255	0	45.88	127.1	7.43	4.02	-2.2	-0.02
	Residential Area	255	0	49.90	124.9	7.45			
Deviation Image	Total Area	255	0	29.11	57.0	6.32	12.07	16.7	0.75
	Residential Area	255	0	41.18	73.7	7.07			
Fourier Feature Image	Total Area	255	0	36.80	149.7	7.12	5.26	-4.2	0.20
	Residential Area	251	3	42.06	145.5	7.32			
Symbiotic matrix Feature Image	Total Area	255	0	20.34	33.3	5.14	-1.74	-6.0	-0.19
	Residential Area	255	0	18.60	27.3	4.95			

Table 1 also calculates the difference of the statistic data such as the difference of deviation, difference of average and difference of entropy between the total image region and the residential region image manually selected from the total image. These differences of the gray value statistic data show the degree of the difference between the residential area image and the total image and these differences are very important to the segment threshold value selection. And the image segmentation will be better if the difference of the gray value statistic is high. From the result of Table 1, the difference of the gray value statistic data between the total image region and the residential image region manually selected is very low (difference of deviation is 4.02, difference of average is 2.2 and difference of entropy is 0.026) and it means that it's very difficult to extract residential area from the test image just using the grey

histogram statistic data. After transferring the image to the deviation texture images, the difference of the gray value statistic data has been greatly increased (difference of deviation is 12.07, difference of average is 16.7 and difference of entropy is 0.75). Thus, for the deviation texture image, it's easy to obtain the segmentation threshold for the residential area extraction just using the grey histogram statistic data. And the difference of the gray value statistic data to the Fourier texture image and grey symbiotic matrix texture feature image just increase a little and for the symbiotic matrix texture image, one of the differences becomes small. Thus, we can get the conclusion that the deviation texture analysis is better for the image segmentation while the Fourier texture transformation and the grey symbiotic matrix texture feature analysis have not obvious effect, which is coincide to the view effect analysis to above texture images.

2.3 Self-adaptive segmentation threshold Using Gauss Blur

The residential areas pixels in the original images are consist of mixed pixels with both light pixels and dark pixels. And the dark pixel in the residential area is simulated to the background pixel, thus it's very difficult to obtain the suitable threshold value directly using the original image to classify the residential area and the background. From the above texture analysis to the residential area images, even the deviation texture image increases the difference between the residential area pixels and the total image pixels, then some background object will be included in the residential area. And the interior composing of the residential area is very complex and the texture character changes are huge which make it very difficult to get the suitable segmentation threshold value and extract the residential area through one time region growing (Vairy M, 1995, Chang YL, 1994). And the mixed pixel make the region grow difficult using the simple seed. This is the main error source for the residential area extraction.

Considering the extraction of residential area focuses on the board, the details of the residential area are not very important for the extraction result while the inside details with large

statistic difference have great effect to the board extraction result of the residential area. Thus some methods are proposed to process the inside details in the residential area to ignore or blur them. And Gauss blur is a good solution.

Figure 3 is the gauss blur results of the original image and deviation image.

As Figure 3 shown, the gauss blur make the deviation texture image consistency grey distribution inside the residential area and high contrast to the background. Thus the self-adaptive threshold can be easily obtained and the extraction can be well done. And the statistic data of these images and the residential image region manually selected from the total images are also calculated as Table 2 shown.

These differences of the gray value statistic data in the Table 2 the show the degree of the difference between the residential

area image and the total area image. And the deviation of the residential area pixels presents the grey distribution consistency. If the deviation is low, the grey distribution consistency is high for the threshold calculation.

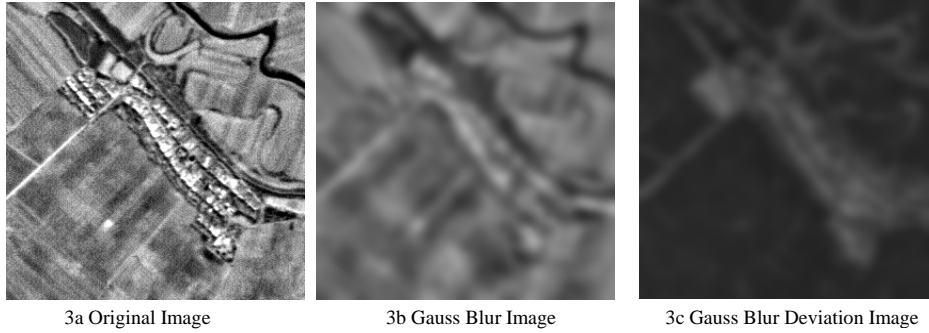


Fig 3 Comparison of Gauss Blur Image

Table 2 Comparison of the statistic data in the original image and gauss blur images

Feature Value		Max	Min	Dev	Aver	Entropy	Dif. Of Dev	Dif. Of Aver	Dif. Of Entropy
Original Image	Total Area	255	0	41.27	128.7	7.30	8.46	-1.8	-0.48
	Residential Area	255	0	49.73	126.9	6.82			
Gauss Blur Original Image	Total Area	180	58	19.03	128.9	6.53	-4.63	-8.1	-0.70
	Residential Area	162	64	14.40	120.8	5.83			
Gauss Blur Deviation Image	Total Area	100	38	12.04	57.4	6.27	-7.30	26.5	-2.05
	Residential Area	95	74	4.74	83.9	4.22			

As Table 2 shown, the difference values of statistic data of the gauss blur images lessen while the grey range is half of the original image (the grey value range of original image is 0 to 255 while the grey value range of gauss blur deviation image is only 74 to 95), thus the absolute difference of deviation increases too, which means the gauss blur can further improve the effect of the threshold selection. The most important point is the high increasing of the average difference especially the gauss blurring result of the deviation texture image (difference of average is 26.5, the variation of the average between the original image and gauss blur deviation image is 28.3 which is large than the difference of the deviation and average in the texture image, Section 2.2). In this step, the average can be used as the threshold feature for the segmentation of the gauss blur image to obtain best extraction result of the residential area.

2.4 Residential Area Extraction from Texture Feature Images

With the self-adaptive threshold, the coarse segmentation image can be obtained. While the outer roads always connect to the residential area and have similar feature to the roads inside the residential area. Thus some outer roads are included in the residential area. Skeleton processing is proposed to eliminate the road from the residential area. The outer roads have low width of skeleton, thus we can identify the outer roads with the width of skeleton to obtain high precision border of the residential area. Figure 4 is the whole processing flow chart of the residential area semi-automatic extraction in the high-resolution image

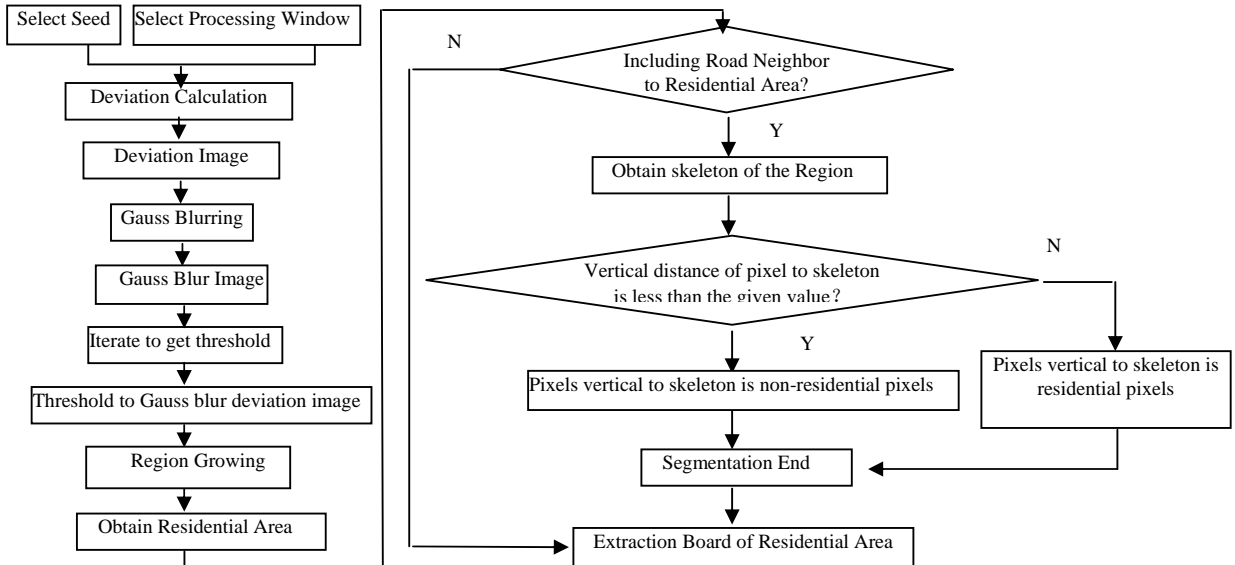
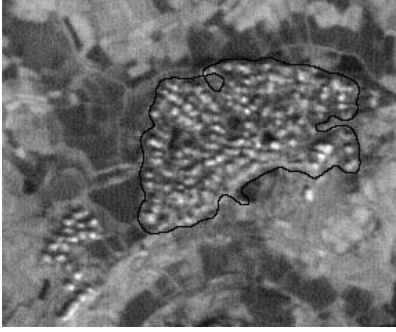


Fig 4 Processing flow chart of the residential area semi-automatic extraction

3. EXPERIMENTS AND RESULTS

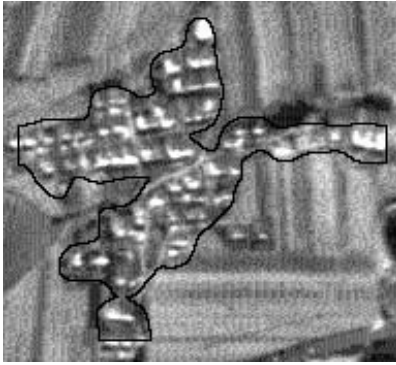
Five high resolution images with typical residential area (country residential area, urban residential area, rarefied and concentrated residential area) are selected for extraction experiment and the resolution is ranged from 3m to 15m. The extraction results are shown as Figure 5, the dark outlines are the extraction board of the residential area.



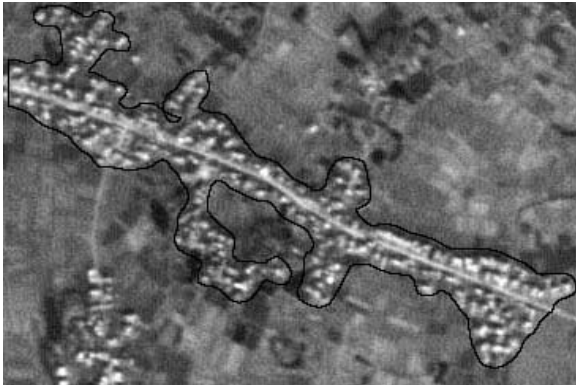
5a



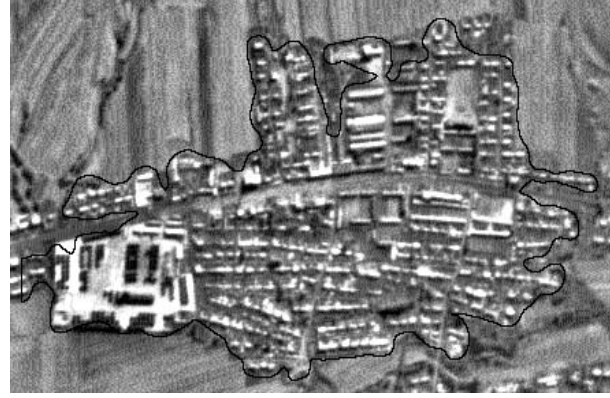
5b



5c



5d



5e

Fig 5 Results of the residential area semi-automatic extraction

Pixel error is taken as the accuracy assessment parameter and it can be simple calculated as the figure 6 shown.

As figure 6 shown, the dark outline is the residential area edge which is extracted by the method proposed in this paper and the area M_1 of the dark outline is the semi-automatic extraction area. The white dark outline is the residential area edge which is the result of view identification. The area M_2 of the white outline is the actual measure area of residential area. Thus, the error extraction pixels and missing extraction pixel of residential area can be determined as figure 6. Where T is the right extraction residential area, F is the error extraction residential area and L is the missing extraction residential area. And the pixel number is taken to calculate the area.

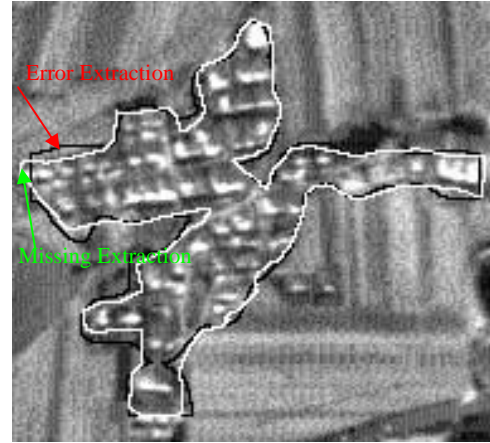


Fig 6 The precision assessment of residential extraction

The right ration, error ration and missing ration of residential extraction can be calculated as following equation and these ratios can be used to analyse the extraction precision.

$$F = M_1 - M_2 \quad (6)$$

$$T = M_1 - F \quad (7)$$

$$L = M_2 - T \quad (8)$$

$$\text{Right Ratio} = \frac{T}{M_1} \% \quad (9)$$

$$\text{Missing Ratio} = \frac{L}{M_2} \% \quad (10)$$

$$\text{Error Ratio} = \frac{F}{M_1} \% \quad (11)$$

The pixels number is selected as the evaluation of the extraction precision and the detailed steps are described as followings:

- (1) Calculate semi-automatic extraction area M_1 pixels and actual area M_2 pixels manually selected of the residential area
- (2) Superpose M_1 and M_2 and measure the right extraction pixels number, the error extraction pixels number and the miss extraction pixels number, calculate correspondence percent. Table 3 shows the precision results.

Neural-Network Structure on a Multi-spectral Land-use/Land-Cover Classification, Photogrammetry Engineering & Remote sensing, 1997, 63(5):535-544

Table 3 Comparison of the semi-automatic extraction (Unit: Pixel)

Image No	M_1	M_2	Right Area	Error Area	Missing Area	Right Ratio%	Error Ratio%	Missing Ratio%
4a	22660	21246	20670	1990	576	91.2	8.8	2.7
4b	13221	13465	12825	396	640	97.0	3.0	4.8
4c	19235	19254	17944	1291	1310	93.2	6.8	6.8
4d	8535	7885	7722	813	163	90.5	9.5	2.1
4e	55183	59670	54171	1012	5499	98.2	1.8	9.2

As Table 3 shown, the right extraction ratios are all higher than 90%. The average right percent is over than 94.2% and this can meet the requirements of the actual applications.

4. CONCLUSIONS AND DISCUSSIONS

The semi-automatic extraction results of residential areas from different types of high resolution images show that the method is simple and efficient and only takes very short time with the 94.2% correctness to the residential area extraction. And the residential areas extracted by this method are available to provide information for some application such as planning and decision-making. To improve this method to high efficient, the seed selecting should be done with the support of the neighbor characters of the pixel distribution to obtain the better region growing results by the computer.

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