Post Disaster Information Extraction of Damaged Houses from Multi-Scale Image Segmentation

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***Abstract* — Advances in photographic sensor technology for high resolution images has provided opportunities for the application of remote sensing to address the limitations of traditional multi-scale segmentation based on image regions. The paper provides a new method of multi-scale segmentation which is combined with edge detection and regional feature detection. We use nonlinear filtering to segment, and then extract successfully the information of a house damaged by earthquake. We unite the edge detection method using the Canny operator to increase the confidence of an advanced regional feature detection method of multi-scale segmentation using the Mean Shift operator. The new method limits effectively the phenomenon of both over and under segmentation, while maintaining the space structure of the object. The total confidence value of Kappa reached 0.9623 in the experiment and the time of multi-scale segmentation shortened to less than 20 seconds while processing two images to provide post disaster information.**

Keywords - edge detection; Regional feature detection; nonlinear filtering; multi-scale segmentation; Canny operator; Mean Shift operator

I. INTRODUCTION

With the constant improvement of remote sensing image resolution, the role of remote sensing in various fields deepening, it brings to remote sensing applications opportunities as well as challenges. High resolution remote sensing image containing rich information, many types of feature, traditional methods, such as the method of single information extraction based pixel , which can not make full use of the information contained in the image, so information extraction division become the focus of research.

Multi-scale segmentation is commonly used in object-oriented image analysis method, according to the different object types, it sets different threshold, and analyze targeted object from multiple perspectives, multi-level. In recent years, with the development of computer science, mathematics, the method of multi-scale segmentation is more and more perfect, and obtain a series of achievements, Zhang Gui-feng introduced the granularity concept to the segmentation process of high spatial resolution remote sensing image, Wang Lu proposed the method of selecting segmentation parameter [1].

Though multi-scale method is becoming more and more mature, the applications are still less, especially used to extract information from the natural disaster area. How to use the advantages of high spatial resolution fully to improve the classification accuracy and the reliability of target extraction is of great significance. In this paper, we use the edge constraint with multi-scale and the multi-scale constraint with the fusion of region features to segment image before and after the disaster and extract change information by comparing.

II. MULTI - SCALE EDGE DETECTION BASED ON CANNY OPERATOR

A. Multi - Scale Edge Detection Of The Traditional Canny Operator[2-3]

Canny is the most commonly used edge detection operator, whose parameters are adjusted to identify different edge features according to the specific requirements of different implementations. The traditional Canny edge detection process consists of Gaussian filter used to smooth the image, with the finite difference of the first order partial derivatives to calculate the magnitude and direction of the gradient, the non maximum suppression of gradient magnitude and with double threshold algorithm to detect and connect edge .The optimal operators need to meet the three principles:

SNR criteria: the higher the SNR is, the better the quality of edge detection is.

$$SNR = \frac{\left| \int_{-w}^{w} G(-x) f(x) dx \right|}{n_0 \sqrt{\int_{-w}^{w} f^2(x) dx}} \quad (1)$$

$f(x)$ is the impulse response of the filter, $G(x)$ is the edge, n_0 is the root mean square of Gaussian noise.

Positioning accuracy criterion: the higher the ratio is, the higher the accuracy of edge location is .

$$Locallization = \frac{1}{\sqrt{E\left[x_2^0\right]}} = \frac{\left|\int_{-w}^{w} G'(-x) f'(x) dx\right|}{n_0 \sqrt{\int_{-w}^{w} f'^2(x) dx}} \tag{2}$$

Unilateral response criteria: only one response of single edge

$$x_{\max}(f) = 2x_{ZC} \mid (f) = kW \tag{3}$$

$x_{\max}(f)$ is the distance of the maximum value between two adjacent, k is the coefficient less than1, $x_{ZC}(f)$ is the average distance between zero crossing point, which is calculated as

$$x_{ZC}(f) = \pi \left[\frac{\int_{-\infty}^{\infty} f'^2(x) dx}{\int_{-\infty}^{\infty} f''^2(x) dx} \right] \tag{4}$$

In traditional edge detection, using different standard deviation of the Gaussian filter can get different scales of image edge. Usually using the Gaussian pyramid method and wavelet in multi-scale edge detection [4], which usually combines filter and secondary sampling to generate continuously by reducing the image size. In fact, when the scale is larger, their accuracy of edge will reduce, and the edge position detected will migrate, but using Canny operator to extract the real weak edge to a certain extent [5-6]. Therefore, changing the standard deviation of filter to experiment of multi-scale edge detection has certain defects.

B. Embedded confidence of multi-scale edge detection of the Canny operator

Because the Canny operator is affected by low threshold, when the minor threshold is bigger, some weak edge can not be detected, and when it is set small, it is likely to introduce some detail information or false edge. So some other attributes are needed to constrain edge extraction, which can reduce the noise, as well as extracting weak edge [7-8].

Adding confidence constraint to extract edge operator, at the same time, the confidence and the amplitude is used to inhibit the non-maximum and detect double threshold. The main process is as following:

(1) Eigenvalue calculation

Use Gaussian smoothing operator smoothing images, assume the original function is $f(x, y)$, after smoothing images is $f_s(x, y)$, calculate the mold of gradient f_{Grad}, and then normalize between zero and one, and then calculate the confidence level, which is matching degree an ideal edge image data and the template and is not related to the gradient.

(2) Non maximum suppression

Peter Meer, (2001) found in the edge of the neighborhood pixels, with the increase of distance from the edge to center position, the range of the gradient value and confidence level is reduced gradually, so at the same time, based on the gradient direction and the confidence to eliminate the local maximum value point, obtain the accurate edge position.

(3) Double threshold detection

Use the maximum inhibition to remove noise multiple edges, extract the edge of the single pixel, and then generate strong edge image and the weak edge image, and double threshold detection is used to prevent the false edge. High threshold detect strong edge points; Low threshold rule out the details which is not edge and detect weak edge points [9-11].

Although Canny operator embedded confidence can detect the high accuracy unilateral pixels and weak edge, the final result do not have multi-scale properties. In nonlinear scale space, the edge of the large scale is the simplification of small scale edge character, which is consistent with the scale feature presented in remote sensing image. Using nonlinear filtering operator of different scales to segment image to get multi-scale image. Features location produced by nonlinear filtering in the image of multi-scales don't change much, with high accuracy of object edge, the edge of the coarse scale is the simplification of fine scale edge character, which clearly expresses the features of hierarchical relationships. Therefore, this paper used the nonlinear scale of filter method to express multi-scale, and then extracted the image edge of each scale, using embedded confidence method to extract the edge.

III. EDGE DETECTION COMBINED WITH REGIONAL CHARACTERISTICS TEST OF MULTI-SCALE SEGMENTATION

A. Multi-Scale Segmentation Method Based on Regional Characteristics

Usually segmentation algorithm based on region feature has region-growing method and split merge method. Multi-scale segmentation based on region feature is based on region feature. First of all, we assumed a segmentation scale, generating a segmentation result of small scale, and integrated the small scale of segmentation layer according to the similarity of certain regional, where the regional heterogeneity should be at least, ending up with a larger scale of the segmentation results. The common classification method has the multi-scale segmentation of mean shift method, the multi-scale watershed segmentation method [5] [12].

Mean shift algorithm is a non-parametric iterative algorithm of kernel density estimation. It does not require any prior knowledge and is valid for arbitrary shape distribution of data. The method has simple form, but with the stability, noise immunity and high efficiency [6].

Comaniciu et al., using the mean shift has achieved good results in image segmentation, opens the mean shift algorithm applied in the field of image processing. Jiaxiang Zhou proposed adaptive bandwidth Gaussian kernel mean shift algorithm [7].

$$M_v(x)=\frac{\lambda}{n^{-1}\sum_{i=1}^{n}\tilde{f}(x_i)}\frac{h_0^2}{C}\frac{\hat{\nabla}f_K(x)}{\hat{f}_{G(x)}} \tag{5}$$

λ is the arithmetic mean of $\left\{\tilde{f}(x_i)\right\}_{i=1\cdots n}$.

Specific segmentation process is that initial clustering adopted a given bandwidth parameters, using standard clustering, and the clustering results was used to calculate the bandwidth of the next clustering, the bandwidth of next clustering adaptive.

B. Edge Detection Combined With Regional Characteristics Test Of Multi-Scale Segmentation

While the accuracy of adaptive bandwidth of Gaussian kernel mean shift algorithm mentioned above is improved, it is difficult to achieve the ideal effect dependent on the heterogeneity of the spectrum, which is easy to cause over-segmentation phenomenon. In order to get higher precision of the edge and the distributed evenly segmentation result. We can use edge detection of multi-scale combined with regional characteristics test of multi-scale segmentation, first to detect edges and then using edge constraints to realize image multi-scale segmentation, the segmentation process is as following: (1) use Gaussian smoothing operator to smooth images; (2) express multi-scale image by nonlinear scale filter method; (3) extract edge of a certain scale using Canny embedded confidence; (4) fuse edges and spectral characteristics with adaptive bandwidth Gaussian kernel mean shift clustering to realize automatic image segmentation; (5) merge small object segmentation; (6) repeat (2) - (5), realizing the multi-scale image segmentation.

IV. THE EXTRACTION EXPERIMENT OF DAMAGED HOUSE INFORMATION

With the advancement of "digital city" construction ,the high resolution image is more frequently used .The estimation of damage area is an important aspect of automatically extracting information study, and the traditional method of extracting house and facilities from image already can't satisfy the demand of automatic extraction , which is time-consuming and the accuracy is not very precise .

This paper used the aerial photography of a certain area that before and after the earthquake (figure1) ,the resolution were 1M and 0.5M respectively. When using nonlinear filter to filter the image, then we got nonlinear scale space. Arrange the images by their scale size, with the increase of the scale ,the image information decrease gradually. When the scale comes to the maximum , there were only contour information left in study area such as house and road .After pre-processing ,we do the edge detection and nonlinear scale filtering, and then arrange the image by their scale ,the first image's scale is 0,and the last one is 3.5 ,others' scale increased at the step of 0.5. Then the edge detection Canny operator was used to detect the every scale's edge.

(a) before

(b)after

Figure 1 Images before and after earthquake.

The scale of edge detection is 3 in figure 2.From the figure ,we can see many detail edges and many edges of small size features ,part of the accuracy is not very precise.

（a）before

（b）after

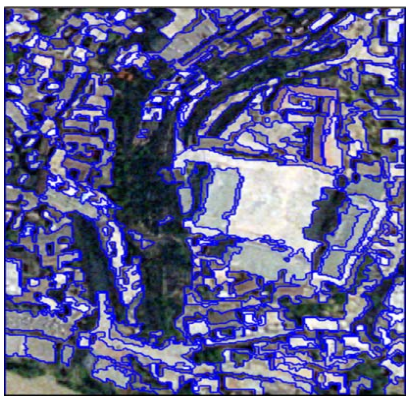
Figure 2 The edge detection results of confidence embed Canny operator.

We united the edge detection and regional feature detection to segment the 8 scales ,the smaller objects were merged , Then chose the evaluation criteria(CU ,OG ,UG) based on overlap matrix as the judge standard ,which was proposed by Oritz. The results were showed in the table 1.

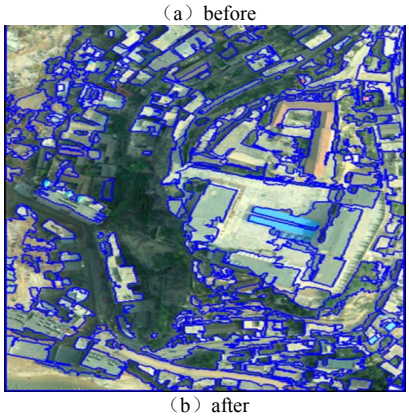
TABLE1 THE COMPARISON OF TWO DIFFERENT METHODS BASED ON OVERLAP MATRIX

Segment scale	CG	OG	UG	Multi-scale segmentation with Canny and regional feature	CG	OG	UG
0	52.16	9.14	36.98	0	71.25	11.65	27.66
0.5	58.61	11.25	34.12	0.5	78.69	18.95	24.69
1	67.23	15.64	29.57	1	82.16	20.71	20.58
1.5	70.89	17.18	24.33	1.5	86.19	22.66	18.65
2	85.64	20.92	19.46	2	89.67	25.98	11.25
2.5	90.56	22.59	12.37	2.5	95.46	26.47	9.87
3	94.79	24.61	4.99	3	96.46	27.91	5.58
3.5	96.17	26.89	4.01	3.5	97.12	27.89	3.91

From the table ,we found that the multi-scale segmentation method which combined Canny operator and regional feature can improve the segmentation accuracy obviously .Figure 3 is the results of segmentation ,from figure 3 we can see the accuracy is relatively high ,the urban artificial building area were extracted precisely .In addition ,the processing time are within 20 seconds , that is to say the segmentation efficiency is relatively high .



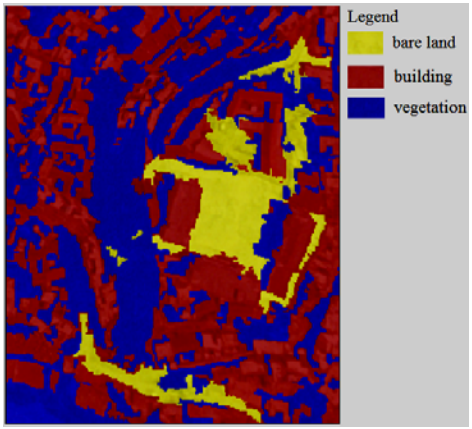
（a）before



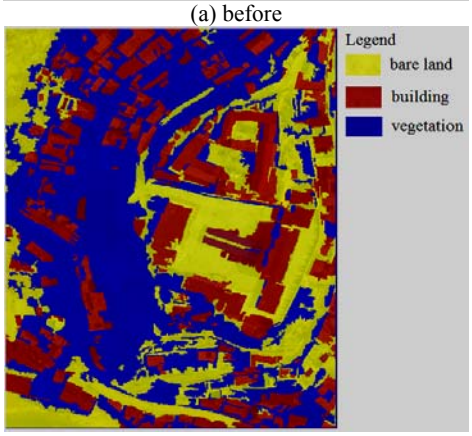
（b）after

Figure 3 Images after segmentation

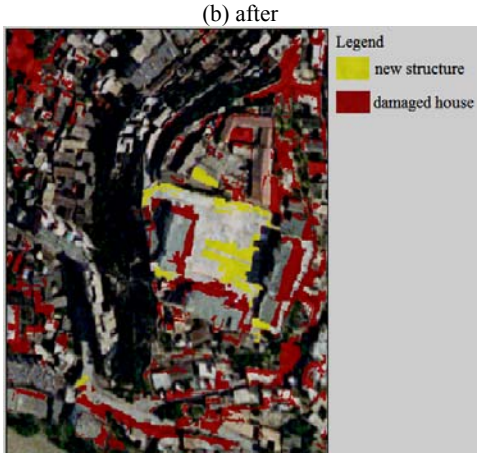
On the basis of the classification result ,we use some software to detect the changes .Figure 4 are image classification results .The red parts in fig (a) and (b) are structures, while it represents bare lands (damaged house) in fig (c),which accounts for 11.263 km^2 .The yellow parts in fig (a) and (b) are bare lands, while it represents structures (new buildings like temporary buildings in the square) in fig (c),which accounts for 300 km^2 .



(a) before



(b) after



(c) Variation before and after the earthquake

Figure 4. Image classification results

This paper choose four indexes to evaluate the accuracy , and they are producer's accuracy ,user accuracy ,overall accuracy and Kappa coefficient .The results of Kappa coefficient were displayed in the table 2 .After analysis ,we found that the multi-scale segmentation method proposed in the paper can meet the requirement , the edge acquired by this segmentation method is more smooth and closer to the true building .Thus ,the classification accuracy is more precise .

TABLE 2 KAPPA COEFFICIENT AND TOTAL KAPPA COEFFICIENT

Classes	Kappa coefficient
Building	0.9449
Bared area	0.9268
Vegetation	0.9317
Total Kappa coefficient：0.9334	

V. CONCLUSIONS

This paper proposed a new method for multi-scale image segmentation which is combined by multi-scale edge and regional feature, the method was successfully applied in the extraction of damaged house information between two images before and after the earthquake. Firstly, the spatial structure of image objects can be well-maintained through the new method .According to the result of segmentation, the new method effectively restrained the phenomenon of over segmentation and under segmentation, the result is more close to the fact and the evaluation is more reasonable. Secondly, we can get the disaster information accurately and timely by applying the method to image processing, thus we can provide safeguard for the subsequent relief work.

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