Detection of buildings from 1m-resolution satellite imagery

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Abstract

Detecting simple shaped buildings from 1m-resolution satellite imagery is presented. The proposed algorithm is that first, image features such as edges are detected and then segmentation process is performed with the detected features. It can be result in line primitives. These primitives are linked and grouped by building hypotheses. Proposed building hypotheses restrict a building to simple rectangular shape. And sub-region homogeneity test is performed for finding rooftops of buildings. The proposed algorithm has been tested on IKONOS satellite image with 1m-resolution.

1. Introduce

Recently, modern electronic and optical technology has made it possible to use a variety of sensor data, including high-resolution satellite such as IKONOS (USA, 1999). Also Korea is planning to launch the satellite (KOMPSAT Ⅱ) which has 1m-resolution in 2004. A satellite image can be used in many application including geographical information systems (GIS), digital elevation map (DEM), town planning or environmental related investigations (Fraser, 2001). However, those images would have limits in some applications if the images have low-resolution. For instance, building detection, it was only possible using aerial images with high resolution. But nowadays many attempts for building detection are being made with high-resolution satellite images.

Extraction of man-made objects such as buildings from digital images is an active topic of computer vision and remote sensing. In the case of aerial images, many methods have been proposed for building detection and description. The main ideas of these are series of modeling of buildings, linear feature extraction, finding outlines of building and segmentation (Lin and Nevatia, 1998). On the other hand, for satellite images, a few studies are proposed. Park et al. proposed a line rolling algorithm for finding missing building lines. They directly created a conjugate anti-parallel line over the roof with detected line (Park, 2000). Sohn et al were using local Fourier analysis to reduce the building hypotheses space in early process (Sohn, 2001).

In this paper, automatic building detection method in high-resolution satellite image are presented. It consists of anisotropic diffusion and grouping with building hypotheses. In spite of a high-resolution satellite image, there are many problems to detect buildings. First problem is its low signal-to-noise ratio (Park, 2000). So we use an edge preservation filter for reducing the noise without loss of features. And linear features of images are extracted for building hypotheses. Then these features are grouped to building candidates using hypotheses.

In the following we describe an edge preservation filter, linear feature extraction and building hypotheses in section 2. In section 3 we present the results on IKONOS image, and the summary and conclusion are presented in section 4.

2. Building detection

Our basic approach for building detection is to use the features of image. An important step in building detection is to determine the position of the edges of the buildings in the image. However, edge extraction is much more difficult because of the presence of noise. Anisotropic diffusion is widely used method for noise reduction, image segmentation and edge extraction (Ye, 2001).

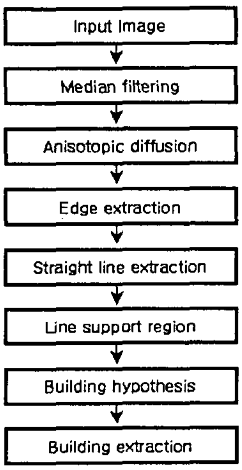


Fig 2.1 Block diagram of proposed building extraction method

In our method, as a preprocessing, anisotropic diffusion method is used, then edges are extracted from the image. As edges are boundaries between objects and background, these edges contains many information about objects. In order to extract salient information of building, straight lines are extracted selectively by SVD line fitting method. Some of the straight lines are principle components of buildings, so these straight lines are combined by building hypotheses with some constraints. For instance, line support region is tested its homogeneity for building hypotheses. It determines whether the line is for building or not. Fig. 2.1 shows the block diagram of our method.

2.1 Anisotropic diffusion

Anisotropic diffusion performs its smoothing action preferably within a homogeneous region rather than across the borders of different regions (Perona, 1990).

This smoothing action can be conceived as a diffusion of the intensity of the image, with a diffusion constant that varies locally and is an inverse function of the gradient magnitude.

In anisotropic diffusion, an image, $I_0(x,y)$ can be diffused by partial difference equation (2.1).

$$\frac{\partial I(x,y,t)}{\partial t} = \nabla \cdot [C(|\nabla I(x,y,t)|)\nabla I(x,y,t) \qquad (2.1)$$
$$I(x,y,0) = I_0(x,y)$$

The diffusion coefficient $c(|\nabla I|)$ is the function of the gradient, $|\nabla I| = \sqrt{I_x^2 + I_y^2}$.

Perona and Malik proposed the diffusion coefficient as :

$$c(s) = \exp[-(\frac{s}{k})^2]$$
$$c(s) = \frac{1}{1+(\frac{s}{k})^2} \qquad (2.2)$$

where k is the constant according to image. The experiments of Perona and Malik were visually impressive in that edges remained stable over a very long time. Edge detection based on this process clearly outperformed the linear Canny edge detector.

2.2 Straight line primitives extraction

An important step in image analysis is to determine the position of the edges of the objects in the image. Edge is the boundary between objects and backgrounds. In the case of building detection, straight lines can be thought as candidates of building boundaries.

2.2.1 Edge detection

Edge map can be extracted in diffused image by linear Canny edge detector (Canny, 1986).

Canny used variational method and the criteria in numerical optimization to derive detectors for several common edges, including step edge. Canny's procedure for finding two-dimensional step edges and other types of edges use directional operators of varying width, length and orientation. This procedure, which includes as an essential part an appropriate thresholding, works remarkably well on real images.

2.2.2 SVD line fitting

Even though image preprocessing, many false edges can be found in edge map. To select true edges of buildings, we found straight lines by using the SVD line fitting method. The Singular Value Decomposition(SVD) of a matrix yields a simple method for fitting a line to a set of points on the plane based on least square error manner. In SVD line fitting algorithm, the residue is the same as :

$$\min_{\|\mathbf{n}\|=1} \| \mathbf{d} \| = \sigma_2 \qquad (2.3)$$

where σ_2 is the smallest singular value.

2.3 Linking and grouping line primitives

Straight line primitives are extracted by SVD line fitting algorithm. But these primitives cannot be considered as a building itself. To emphasize the information of building, linking process must be required.

2.3.1 Linking of primitives

Micheal et al proposed token-based algorithm with perceptual grouping. He regarded the primitives as a token and made some rules of linking condition (Micheal, 1989).

In our approach, the line primitives are selected with strict conditions that include the threshold $\min_{\|\mathbf{n}\|=1} \| \mathbf{d} \| = \sigma_2$, and the primitives are linked with others when they are satisfied below conditions. Fig 2.3 shows the linking conditions.

1. The distance of the end points of the each primitives are smaller than the dynamic threshold. This threshold is varied with the line strength. The stronger the strength is, the bigger threshold is. It can compensate the missing primitives and connect them to strong primitives.

2. The difference of orientation angle between two primitives must be small.
3. The perpendicular distance from other end points to the primitive line must be close. This condition prevents that the parallel but different-offset lines are linked.
4. Ratio of contrast of one primitive to other contras must be close to 1. It can affect to remove the shadow lines.

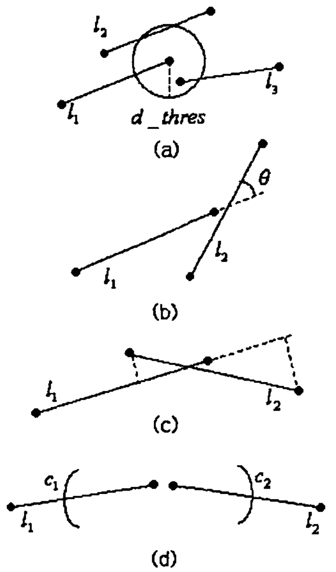


Fig 2.3 Conditions for linking (a) Each endpoints must be close (b) The difference of orientation angle must be small (c) The perpendicular distance must be small (d) The contrast of two primitives must be close to 1.

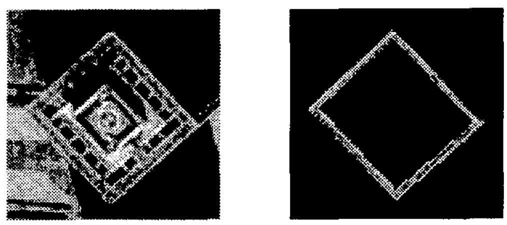
2.3.2 Building hypotheses

Under the assumption that buildings have a simple rectangular shaped, our method find rectangles with the lines. Rectangles are found by clockwise searching algorithm. First, we find the line by searching left to right, top to bottom manners, then clockwise searching algorithm finds the next line in direction of clockwise. The next line must satisfy the condition to become a building.

1. Because the building is rectangular and the image was captured at practically vertical direction to ground, the angle of the two lines must be close to $\pi/2$.
2. The distance of two lines must be close. The measure of "close" depends on its line strength.

This procedure can make all the possible rectangles in the image. The result rectangles are used as candidates for real building. In early study i.e. in aerial image, the roof is considered as a homogeneous region. Candidates could be sorted in the order of its homogeneity. But in the case of ours, the rooftop is not a homogeneous region anymore. Fig 2.4 (a) shows a typical rooftop of building. It has a complex region rather than homogeneous region. In that case, the rooftop is not homogeneous.

In our approach, we test homogeneity for only the area that is close to inner boundary (Fig 2.4 (b)). The line support region is calculated with suitable distance from the lines. By this sub-region homogeneity, we can reduce some false buildings.



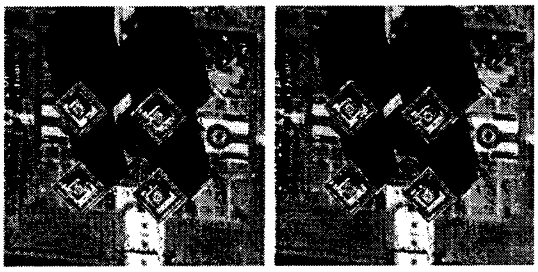
(a) (b)

Fig 2.4 (a) A typical rooftop of building. (b) Its inner close boundary region.

3. Experimental results

Our method is tested on the image, IKONOS with 1m-resolution, taejon area. Because the urban region contains very complex structures, it is impossible to test entire region. So we took the appropriate sample for test.

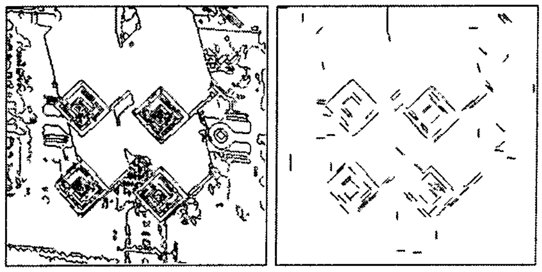
Fig 3.1 shows sample image for our method. It consists of 4 simple rectangular shaped buildings. We first apply an anisotropic diffusion process to the image. Fig 3.2 shows original image and its diffused version. The diffused image seems to be denoisy and edge-preserved. Diffusion parameters are selected considerably based on SNR of image.



(a) (b)

Fig 3.2 (a) Original image (b) its diffused version by anisotropic diffusion

Then edges are extracted by using Canny edge operator. Even though the image was preprocessed, it still has many false edges on it. These edges can be thought as features of image. We apply SVD line fitting algorithm to the edge map. In this step, the selection of parameters should be needed. Strict criteria for line fitting algorithm can product many missing primitives and a loose one product too many false primitives. Fig 3.3 shows edges on image and line primitives with suitable parameters. In this step we found 136 line primitives.



(a) (b)

Fig 3.3 (a) Edge map (b) its line primitives

The line primitives are grouped by the building hypotheses. Our building hypotheses is that building is a simple rectangular shaped one. Each line primitives are tested that it could be linked and it could be grouped, if it satisfy the hypotheses it can be grouped to a building candidate. This process products all possible rectangular shaped regions. We found 31 rectangular shaped regions in this step. Next, the sub-region homogeneity test is applied to rectangular shaped regions. In this step, we could reduce all false regions. Fig 3.4 shows all building candidates and the remaining ones after sub-region homogeneity test. Fig 3.5 shows final detected buildings and its 3D wired frame. The height of building can be calculated by DLT finally (Gupta, 1997).

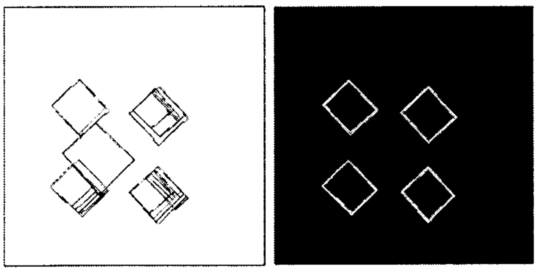


Fig 3.4 (a) All possible buildings. The number of region is 34. (b) Regions after sub-region homogeneity test. The number of region is 4.

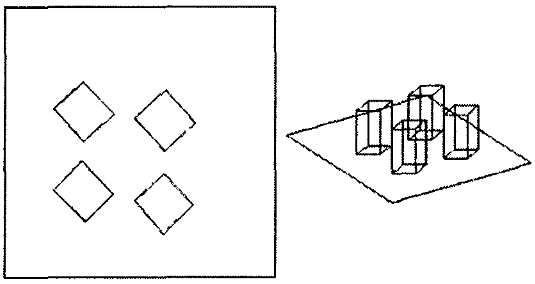


Fig 3.5 (a) Final detected buildings in Fig .3.1. (b) Their Reconstruction of 3D wire frame.

4. Conclusions

Detecting simple rectangular shaped buildings from 1m-resolution satellite imagery is presented. We extracted, first, line primitives that best describe the image features. Then these primitives are grouped into buildings with building hypotheses. We test our method on IKONOS image and it shows good result for some buildings. But there are many problems, too. Line primitives are very sensitive to noise and false line primitives cause to missing buildings. So a robust method for extraction of line primitives is essential.

And we restrict the building to simple rectangular shape. But there are many building against our hypotheses. The extension to a polygon shaped might be a considerable one.

Acknowledgements

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