# Building Detection Using Segment Measure Function and Line Relation


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## Abstract

This paper presents an algorithm for building detection from aerial image using segment measure function and line relation. In the detection algorithm proposed, edge detection, linear approximation and line linking are used and then line measure function is applied to each line segment in order to improve the accuracy of linear approximation. Parallelisms, orthogonalities are applied to the extracted liner segments to extract building. The algorithm was applied to aerial image and the buildings were accurately detected.


## 1. Introduction

Extracting building structures in aerial images is a task of importance for many applications. There have been many previous techniques suggested for building extraction(Mohan and Nevatia, 1989)(Kim and Muller, 1994)(Huertas and Nevatia, 1988)(Venkateswar and Chellapa, 1990)(Collins et al., 1995). Building detection requires robust segmentation techniques to infer the building structure. These methods rely on edges or region extracted from the image and use perceptual grouping or line relation graph to extract the building boundaries. Simple edge-based methods attempt to collect linked edge curves into the desired object boundaries, and succeed only for relatively simple scenes. A system described in Collins(1995) uses corners and straight line segment as low level feature and then feature relation graph is used to extract polygonal rooftops in aerial imagery.

Model based techniques have shown interesting performance but on limited examples. These methods require priori shape models(Weidner and Förstner, 1995)(Gülch and Müller, 1997).

A building is modeled as the union of one or more rectangular parallelepipeds. In this paper we deal primarily with the line segments corresponding to the intensity edges in the scene.

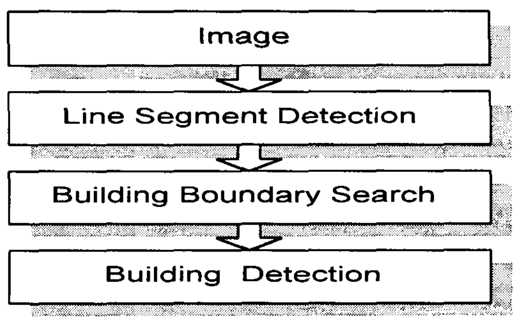



Fig. 1. A schematic diagram for building detection

Our method consists of the following steps. Line segment detection consists of edge detection, linear approximation and line linking. Line measure function is applied to each linear segment in order to find the accurate position of line segment in linear approximation. Line relations between lines are searched. Parallelisms, orthogonalities and intensity constraint for building roof are applied to the line segments(Fig.1).

## 2. Line Segment Detection

Edge elements are extracted by Prewitt gradient mask and edge tracing algorithm used in Choi(1989). Edge elements are divided as long as they fail some fitting condition. Given a edge elements, a straight line between its ends points is drawn. For every point on the edge elements, its perpendicular distance is computed to the approximating line. If it is not everywhere within some distance, the edge element farthest from the approximating line is chosen as a new breakpoint and the edges elements are divided into two new line segments. Recursively this algorithm is applied to the two new segments. After approximating edge elements, small lines are merged to form a long line. The line segment is defined with its end points.

An approximated segment has low position accuracy in some condition. It is necessary to correct the location of the segment. Edginess is a function of the image gradient magnitude and the local orientation of the gradient around edge element. Formally we denote as $f(s_m, \theta)$ the function that measure the edginess of each element in line segment(Bignone, 1995). One can define $f$ by the average image gradient magnitude along the edge or the variance of the local direction of that same gradient. The function $f$, defined in equation (1), is a combination of the image gradient magnitude $\|G(r)\|$ and the local orientation $\theta(r)$ of the same gradient. Fig. 2 shows the notations. Bold line represents the edge elements and dashed line parallel to bold line is virtual line for computing edginess of edge elements. The virtual line rotates within a predefined degree to find the correct location of the segment(Fig. 3).

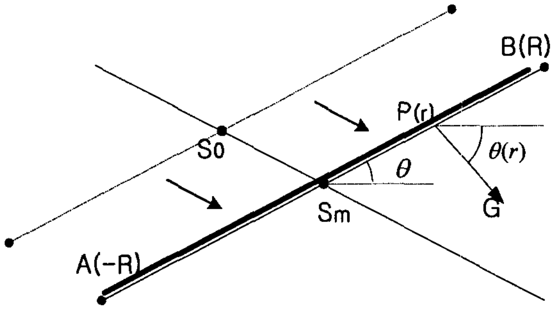



Fig. 2. Notation for segment measure function.

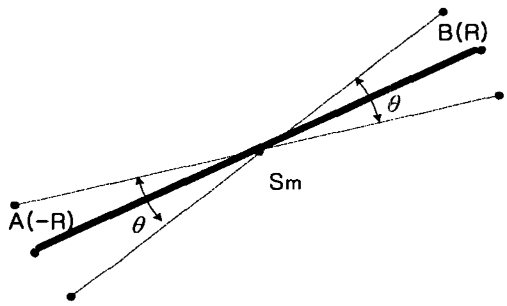



Fig. 3. The correct location of the approximated segment.

$$f(s_m, \theta) = \sum_{r=-R}^{r=R} \|G(r)\| \cdot e^{-\frac{\sin^2(\theta - \theta(r))}{k}} \quad (1)$$

This function $f$ has some properties which make $f$ appropriate for an edginess measure. $f$ is maximum if $(A, B)$ is an edge, then $f$ is approximately the sum of image gradient magnitude along that edge and $f$ decreases quickly, according to the orientation selectivity $k$, if $(A, B)$ is not an edge or is not well located. Even if the edge is only partially defined in the image(occluded or broken), $f$ has a high value. For an approximated segment, a midpoint( $s_m$) is calculated from two end points of the segment. Knowledge about the line segment allows us to restrict the range of $\theta$. To find the maximum of $f$, we discretize it on a regular mesh labeled by discrete values of $\theta$ and $s_m$ and search for peaks in the mesh. Fig. 4 shows an example of the discrete form to find the local maxima.

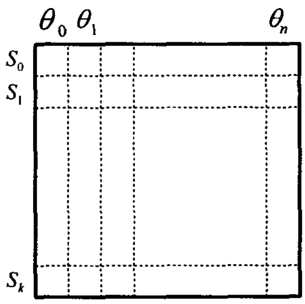



Fig. 4. Discretization of segment measure function.

### 3. line relation and connection

There are three types of connection between lines. Fig. 5 illustrates these types. A line has "start" point and "end" point to define the direction of the line.

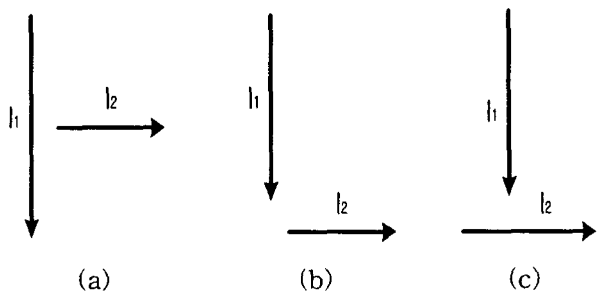



Fig. 5. Three types of line connection.
(a) Type 1: T-junction( $l_1$:top) (b) Type 2: L-junction (c) Type 3: T-junction( $l_1$:stem)

Line $l_1$ and line $l_2$ form T-junction or L-junction. Line $l_2$ has the direction which locates a corner between line $l_1$ and $l_2$ in the left side of line $l_1$. Line $l_2$ is connected to line $l_1$ if the angle between line $l_1$ and $l_2$ satisfies the criteria for connection and the distance from end point of each line to the other line is within the distance proportional to the lengths of line $l_1$ and $l_2$.

### 4. line grouping

It is assumed that the boundary of a building consists of lines and the lines of a building makes a closed loop. Line connection between lines is the first step to find closed loops. The method to group lines is as follows.

1) Define the direction of line $l_i$ and assign label 1 to line $l_i$.

2) Find a new line $l_k$ forming T-junction or L-junction in the left side of line $l_i$ and assign label 2 to line $l_k$.

3) For the line $l_k$, repeat step 2). If a line forms T-junction or L-junction, assign increased label to the line by one.

4) Repeat step 2) and step 3) until the line of present label equals the line of label 1.

Fig. 6 shows an example to find possible closed loops starting from line $l_1$. There are two open loops and one closed loop. For the lines of the closed loop, the cost function, defined in equation (2), is calculated to accept the lines as building roof. Function $P$ considers parallelogram of the lines and function $G$ considers the lengths of the lines forming building roof.

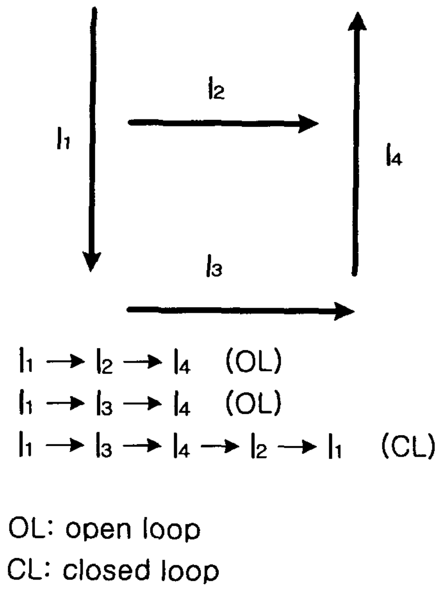



Fig. 6. Trace of continuous boundaries

Function $C$ is a weighted combination of function $P$ and $G$. Fig. 7 shows the notation for cost function used in equation (2).

$$C = w_1 \cdot P(l_1, l_2, l_3, l_4) + w_2 \cdot G(l_1, l_2, l_3, l_4) \quad (2)$$

$$P(l_1, l_2, l_3, l_4) = \frac{1}{\sum_{i=1}^{4} d_i}((d_1 + d_3)\cos(\theta_1 - \theta_3) + (d_2 + d_4)\cos(\theta_2 - \theta_4))$$

where $\theta_i$ is the orientation of line $l_i$.

$$G(l_1, l_2, l_3, l_4) = \sum_{i=1}^{4} k_i \frac{d_i}{distance(l_i)}, \quad k_i = \frac{d_i}{\sum_{i=1}^{4} d_i}$$

where $distance(l_i)$ is the distance between neighbor intersection points with $l_i$.

In some cases, we consider the formation of U structures which capture 3 sides of a parallelogram. U structures are formed when two junctions are aligned. If the value of segment measure function between two end points located in the open side is higher than certain value, a line segment is added in U structure to form a closed loop. Finally we examine the parallel lines which have similar length and intensity. We add the remaining two lines if segment measure function is higher than certain value.

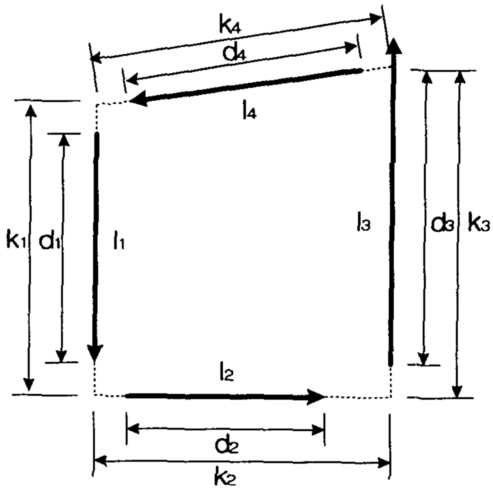



Fig. 7. Notation for the calculation of cost function for the lines of closed loop.

## 5. Results

The algorithm was applied to an aerial image shown in Fig. 8 provided by ETH Zurich.

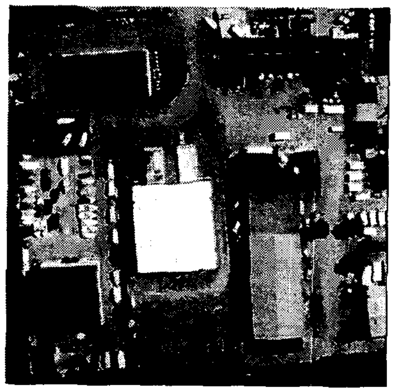
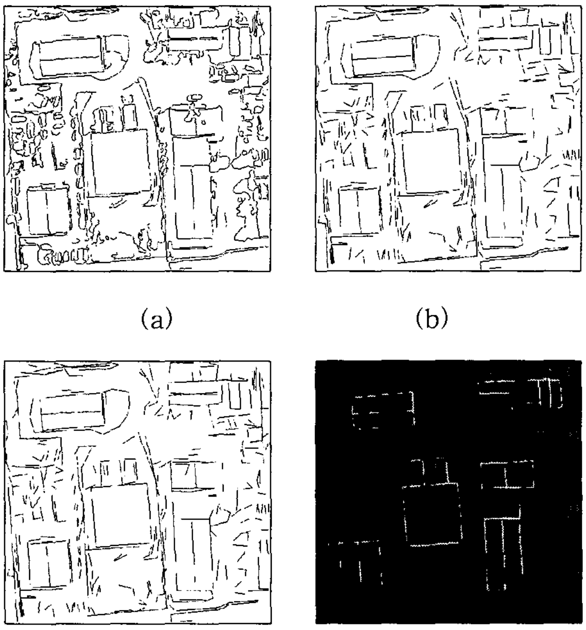


Fig. 8. An aerial image.

After applying Prewitt gradient mask and edge tracing algorithm, edge image was extracted as shown in Fig.9a. Fig.9b shows the lines detected by linear approximation. Segment measure function is applied to each linear segment and line linking was carried out(Fig.9c). The building obtained by grouping lines is shown in Fig. 9d.



(a) (b) (c) (d)

Fig. 9. (a) edge image (b) linear approximation (c) line linking (d) detected buildings.

## 6. Conclusions

In this paper, an algorithm for building detection from aerial image using segment measure function and line relation was proposed. In the detection algorithm proposed, parallelisms, orthogonalities constraint in building roof are applied to the extracted liner segments. This detection technique showed good results when the buildings are rectangular or composed of rectangular components.

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