

EDGE EXTRACTION ALGORITHM BASED ON LINEAR PERCEPTION ENHANCEMENT

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ABSTRACT:

Edges are very important clues for building reconstruction in city-modeling. But some weak edges, such as roofs' ridges, are often similar to the background in intensity which causes low gradient magnitude. The previous edge detection algorithms are hard to detect weak edges with tight threshold, while loose threshold will lead to lots of false edges caused by noise and interference. A linear features perception based edge detection algorithm is proposed in this paper. The human visual mode of linear perception is used as reference, and weak edges are picked according to their linear distribution. The experiments on aerial images of different areas show that the proposed algorithm has a significantly enhanced ability to detect weak edges and suppress false edges comparing with Edison edge detection algorithm.

1. INTRODUCTION

Edges are very important clues for building reconstruction, so edge detection is a basic processing in city-modeling. Some useful weak edges of city-modeling objects, such as roofs' ridge, are often similar to the background in intensity which usually causes low gradient magnitude as shown in the Figure 1.



Figure 1. Weak edges of roof's ridges

However, most previous edge detection algorithms are gradient-based methods(Canny 1986; C.Gonzalez and E.Woods 2002), they detect edges on the basis of the discontinuity in intensity between object and background. So, these algorithms have problems to detect the weak edges: with tight threshold can't detect weak edge, while with loose threshold will lead to lots of false edges caused by noise and interference. To solve this contradiction, Canny introduced threshold with hysteresis to gain better separation between signal and noise(Canny 1986), He and Wang do twice edge detection with tight and loose thresholds separately, then process the two results to get reasonable edge points(He and Tang 2005; Wang and Wang 2006). But these methods only select and link the candidate edge points locating in the neighbouring area of the reliable

edge points and ignore the global characteristic presented by the edge points. Global characteristic is important information for human vision to detect weak edges, human can recognize the weak edges that can form into a straight line or a regular curve. Based on this assumption, the weak edge with regular distribution can be easily detected.

An edge detection algorithm based on linear perception is introduced, the algorithm use the human visual mode of linear perception as reference, and pick weak edges according to their linear distribution. It has a significant enhanced performance to detect weak edges and inhibit false edges.

2. EDGES CLASSIFYING AND MAIN IDEA OF THE ALGORITHM

The most popular edge detectors are gradient-based technique which is on the assumption of the change of intensity value. In fact, useful edges for city-modeling in aerial images may be missed because of low gradient magnitude, while discontinuity in intensity caused by noise and interference may be falsely recognized as edges. Therefore, the edges detected by gradient-based technique can be classified into three types: strong edges, weak edges and false edges, their different characteristics in intensity, gradient and shape are shown in the Figure 2. Strong edges have evident contrast with background in intensity and cause higher gradient magnitude, the edges are continuous and steady, strong edges usually are useful edges. Weak edges are useful edges as mentioned above, weak edges' intensity and gradient are not as ideal as strong edges', and they are detected as a lot of broken line segments with regular distribution. False edges come from noise or the intrusive information that are useless for city-modeling such as trees, their characteristics of intensity and gradient are similar to weak edges', they are also detected as broken segments, but the segments' distribution are not regular but scattered.

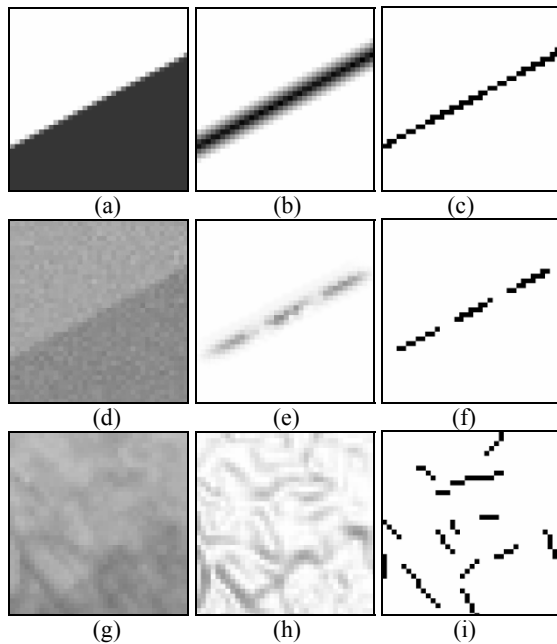


Figure 2. Sketch map of different edge types. (a)(b)(c) Intensity, gradient and detected shape of strong edge. (d)(e)(f) Intensity, gradient and detected shape of weak edges. (g)(h)(i) Intensity, gradient and detected shape of false edges.

The aim of the algorithm is to keep useful edges (include strong and weak edges) and get rid of useless edges (include false edges). The strong edges have distinct characteristic, they are hard to confuse with the other two. So, the crux is how to distinguish weak edges from false edges. There are some similar characteristic between weak edges and false edges: they are both detected as broken segments and the difference in intensity is not so obvious. But the distribution of weak edges is so regular that it is sensitive to our vision. However, the previous edge detection algorithms ignored the regular distributing, they mainly focused on local intensity change and the neighbouring relation between certified and candidate edge points. It led to the losing of weak edges with slim difference in intensity. The main idea of the proposed algorithm is that simulate the sensitive perception of human vision to regular distribution, and investigate the distribution characteristic of edges in a global view, then pick, link and expand the weak edges. For example, an edge is short and with low gradient magnitude, if it can form into a line with some other edges, the edge will be marked as candidate edge to gain further processing, otherwise it will be deleted.

3. ALGORITHM DESCRIPTION

The flow of the proposed algorithm is shown as Figure 2. In preliminary edge detection procedure, credible edges can be gained by previous edge detection algorithm with tight thresholds and candidate edges can be gained by the same algorithm with loose thresholds. All the detected edges are fitted into line segments, and the segments' parameters in polar coordinates system are calculated in the line fitting procedure. Then, the candidate edges are grouped, picked and linked under the idea of linear perception, in this procedure, most false edges are deleted. And then, expand the edges from their endpoints to gain more complete edges. At last, the result of edge detection with more weak edges and less false edges are output.

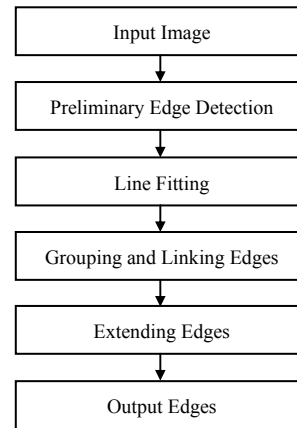


Figure 3. The flow chart of the proposed algorithm

3.1 Preliminary Edge Detection

Edison algorithm(Meer and Georgescu 2001) is improved based on Canny edge detection algorithm, and it applies embedded confidence to all procedures of edge detection and satisfies the three performance criteria for detecting edges: good detection, good localization and only response to a single edge(Canny 1986). Embedded confidence is the information which is independent from gradient estimation and used for evaluating the comparability between data model and ideal edge model, thus, can detect edges of all kinds of figures by reducing the uncertainty in edge detection(Jiang 2004). So, we adopt Edison algorithm to perform preliminary edge detection.

In this procedure, credible edges can be gained by using tight thresholds and candidate edges can be gained by using loose ones. Credible edges are strong edges, most of them are useful edges; while candidate edges consist of weak and false edges, both useful and useless edges are included. Therefore, candidate edges are main part in the next procedures.

3.2 Line Fitting

Line fitting is aimed at finding out the linear feature shown by the edges and calculating the parameters of θ and ρ in polar coordinates system. It could be a good preparation for the next procedures. Hough transform has been widely used as a typical algorithm. But Hough transform is a global calculating process, it is hard to detect short segments, because the voting mode and accumulation has problems that the peak value caused by the isolated points forming into line by accident is higher than the peak value caused by short segments, and the segments at a distance but with similar parameters effect each other(Furukawa and Shinagawa 2003). The proposed algorithm solves these problems with localized Hough transform. We clustered edge points into edge strips according to their neighbouring relationship. Then, calculate the parameters of each edge strip respectively by Hough transform, the process could avoid the negative effect brought by global calculating, and gain a clear peak value even when processing on short segments. To reduce the computational complexity and accelerate the computational speed of Hough transform, the numerical interval of parameter space can be extend properly, after voting, get the points voting for the peak value to fit an accurate line by least square.

3.3 Grouping and Linking Edges

Traditional methods of perception grouping only considered

similarity, proximity and extent between segments(Ralescu and Shanahan 1995). In order to decrease the uncertainty of grouping, the proposed algorithm considers related information of the pixels between the line segments which deserve to be grouped. Reasonable grouping which is accordance with the feature of linear perception can be gained and most false edges can also be removed. The procedures of grouping and linking are as following:

(1) Grouping the line segments according to their spatial relationship. Divide the segments to $180/\alpha$ groups according to their θ value and with the interval of α degree (α is an integer can be 180 divisibility). Then, divide each group again according to their ρ value. From the formula $\rho = x \cos \theta + y \sin \theta$, we can get that if θ value has a slim difference of $\Delta\theta$, the difference of ρ value is

$$\Delta\rho = |x \cos \theta + y \sin \theta - x \cos(\theta + \Delta\theta) - y \sin(\theta + \Delta\theta)| \quad (1)$$

By the influence of the value of x and y , the difference of ρ increases many times as the difference of θ (Huang 2006). So, before dividing according to ρ value, the segments must be rotated to get a uniform θ value. The proposed algorithm employs the average θ value with the weight of their length:

$$\bar{\theta} = \frac{\sum l_i \theta_i}{\sum l_i} \quad (2)$$

Where l_i = length of segment i
 θ_i = θ value of segment i

After the twice grouping, the segments with similar θ and ρ value are gathered into the same group, it means that the segments in a group are collinear. Then, check the proximity for the segments in each group, delete the segments without proximity.

(2) Pick out reasonable group by considering related information of pixels between segments. Firstly, construct a buffer area between the segments, apply nonmaxima suppression to the pixels in the buffer area, and store the maxima pixels. Secondly, search the maxima pixel from one endpoint to the other, typical search result is shown in the Figure 4. The fitting factor and continuous factor of the maxima pixels decide the reasonability of the group. Formula to calculate the probability of a reasonable group is

$$P = w_1 \left(1 - \frac{\sum (\Delta d_i)^2}{l-b}\right) + w_2 \frac{l-b}{l} \quad (3)$$

where P = reasonable probability
 l = length of the buffer area
 b = count of discontinuous pixels
 Δd_i = difference of distances from pixel i and pixel $i-1$ to the line segment
 w_1, w_2 = weight of fitting factor and continuous factor

So, $1 - \frac{\sum (\Delta d_i)^2}{l-b}$ indicate the fitting factor, and $\frac{l-b}{l}$ indicates the continuous factor, both of the two values range form 0 to 1. Experiments show the influences of the two factors are probably equal, so $w_1 = w_2 = 0.5$ is employed as experiential value, the P value for the three situations of (1)(2)(3) in Figure

4 are 0.891, 0.723 and 0.750, we can get the conclusion that the situation of

(1) is the most reasonable grouping and the conclusion accords with the rule of objectivity.

(3) Finally, link the reasonable grouping and mark them as credible edges.

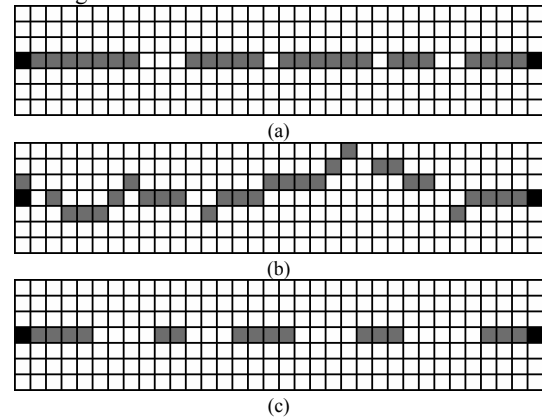


Figure 4. Sketch map of pixels with maxima in buffer

3.4 Extending Edges

Sometimes, weak edges can not be detected because of gradient magnitude not reaching the loose threshold. Extending the edges, we can get such edges which can not be detected before.

Searching maxima pixels from edge extension is similar to searching in the grouping and linking edges procedure: set up the buffer with certain width on the edge extension line, apply nonmaxima inhibition to the pixels in the buffer area, and go along with the extension to search the maxima pixels from each endpoint in turn, then calculate the probability for extension to certain length according to formula (3). Keep on searching when the probability is above certain threshold, then mark extension as credible edges; stop searching when the probability is below certain threshold or arriving at the boundary of the image.

Concluded the credible edges marked all above procedure, the edge detection results can be gained using proposed algorithm. The enhancing effects on typical weak edges of each procedure are shown in Figure 5.

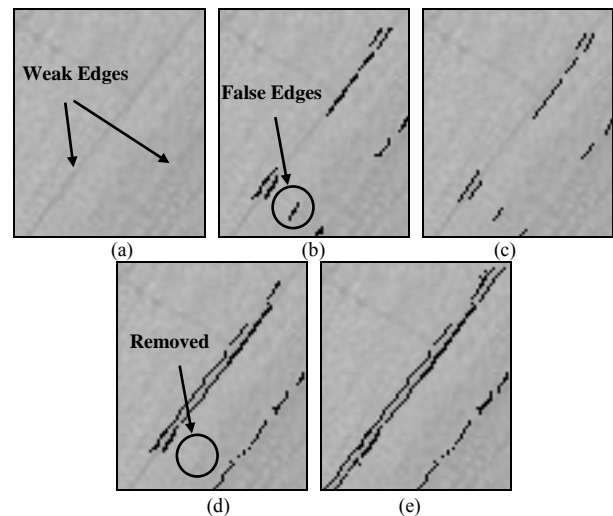


Figure 5. Processing on weak edges. (a) An image with some weak edges. (b) Preliminary edge detection result (c) Line fitting result. (d)

Grouping and linking edges result. (e) Extending edges result.

4. EXPERIMENTS AND ANALYSIS

The experiments compared proposed algorithm with Edison algorithm using two aerial images of different areas. The first experiment could certify the ability of detecting weak edges for less interruption included in the image; while the second experiment employed an image with more interruption to certify that it can inhibit false edges. Because tight and loose thresholds are necessary to the proposed method, so the procedure of experiment is that: the both tight and loose thresholds were applied to Edison algorithm respectively, and two edge detection results were gained at first; then the proposed algorithm used the both thresholds simultaneously to detect edge and gained another result; compared the edge detection results at last. The key parameters in the experiments are shown in table 1. Where *Rank* is normalized ranking of gradient magnitude. The image adopted by the first experiment is taken from an airport, as Figure 6(a), including airplane, runway, few buildings and grass. Edison algorithm detected some edges by using tight thresholds, such as the boundary of buildings and figure of airplane, but the boundary of runway was missed, as shown in Figure 6(b). The runway could be

detected by using loose thresholds, but gained lots of false edges caused by interruption and noise, as shown in Figure 6(c). Using the proposed algorithm, a lot of weak edges of runway has been detected. Especially when comparing dotted elliptic area in Figure 6(c) with the area in Figure 6(d), the proposed algorithm can detect the runway edges which are missed by Edison algorithm using loose thresholds. But a part of false edges couldn't be deleted, such as the dotted rectangular area.

In city-modeling, the roof structure presented in ridges is important information of building reconstruction. The ridges belong to the weak edges because of minor intensity difference around them. The image of second experiment was taken from residential area, as shown in Figure 7(a). A few ridges could be detected by Edison using tight thresholds, as shown in Figure 7(b), more ridges could be detected after using loose thresholds, but some false edges also were detected, as shown in Figure 7(c). Using proposed method, the relative completed ridges has been detected, and has inhibited the interruption from surroundings, especially the false edges brought by trees in the dotted rectangular area, as shown in Figure 7(d). Unfortunately, some line segments on the road haven't been removed. It is because the linear edges in the roads follow the rule of weak edges.

	Window size	Hysteresis high threshold			Hysteresis low threshold		
		Rank	Confidence	decision boundaries	Rank	Confidence	decision boundaries
Tight threshold	5×5	0.93	0.96	Box	0.99	0.91	Ellipse
Loose threshold	5×5	0.93	0.93	Box	0.77	0.77	Ellipse

Table 1. The key parameters in the experiments



Figure 6. Results of the first experiment. (a) Input Image. (b) Result of Edison algorithm with tight thresholds. (c) Result of Edison algorithm with loose thresholds. (d) Result of the proposed algorithm.

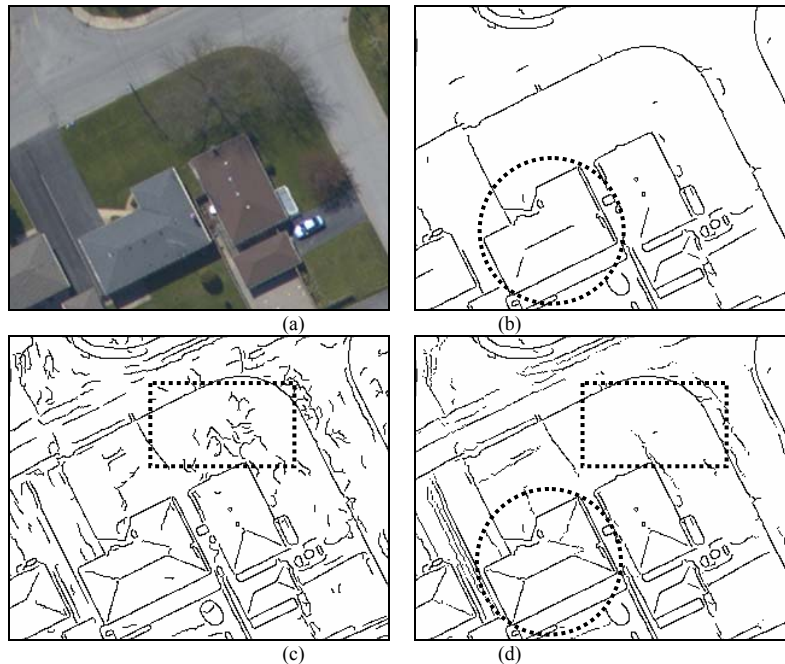


Figure 7. Results of the second experiment. (a) Input Image. (b) Result of Edison algorithm with tight thresholds. (c) Result of Edison algorithm with loose thresholds. (d) Result of the proposed algorithm.

5. CONCLUSION

An edge detection algorithm based on linear perception is proposed, the algorithm use the human visual mode of linear perception as reference to enhance the performance of detecting weak edges and inhibit false edges. The proposed algorithm and Edison algorithm are compared using different aerial images. The experiments show that the proposed algorithm can enhance the ability of detecting the edge in different images. Therefore, the edge detection method based on linear perception is effective and applicable. The method can be improved in the further study: regular curve can be easily detected by human vision, it makes that it's possible to enhance the detection on weak edges forming into regular curve; furthermore, the more continuous and completed edges can be detected if taking the integrality of the object's edge structure into consideration.

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