Comparison for Edge Detection of Colony Images

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Summary

The extraction of features such as edges and curves from an image is useful for many purposes. Features, such as edges and curves are useful in i) texture analysis ii) 3-D surface restructuring iii) segmentation iv) image matching. Edges are important features in an image since they represent significant local intensity changes. They provide important clues to separate regions within an object or to identify changes in illumination. Most remote sensing applications use edge detection as a preprocessing stage for feature extraction. Real images, such as remote sensing images, can be corrupted with point noise. The real problem is how to enhance noisy remote sensing images and simultaneously extract the edges. Using the implemented Canny edge detector for features extraction and as an enhancement tool for remote sensing images, the result was robust with a very high enhancement level. Otherwise, the idea of using both intensities and spatial information has been considered to take into account local information used in human perception. The approach proposed here is strongly related to this idea. The search strategy is based on a Genetic Algorithm (GA) that allows us to find suitable approximated solutions treating the problem as a global optimization technique.

Key words:
Canny edge detector, Edge detection, genetic algorithm

1. Introduction

A large number of edge detection techniques have been proposed. The common approach is to apply the first (or second) derivative to the smoothed image and then find the local maxima (or zero-crossings).

An important issue in edge detection is the scale of detection filter. Small-scaled filters are sensitive to edge signals but also prone to noise, whereas large-scaled filters are robust to noise but could filter out fine details. Multiple scales could be employed to describe and synthesize the varieties of edge structures. Mallat [1] illustrated mathematically that signals and noise have different singularities and edge structures present observable magnitudes along the scales, while noise decreases rapidly. With this observation, Xu et al. [2] proposed a wavelet-based spatially selective filtering technique by multiplying the adjacent scales. Sadler and Swami [3] applied the wavelet-multiscale-products to step detection and estimation and Bao and Zhang [4] presented a denoising scheme by thresholding the multiscale products.

Canny [5] first presented the well-known three criteria of edge detectors: good detection, good localization, and low spurious response and showed that the optimal detector for an isolated step edge should be the first derivative of Gaussian.

Edge detection of images does not admit a unique solution because subjectiveness and contest may take part in the decision phase. It follows that general solutions are not possible and each proposed technique can only be used to solve a class of problems. The approach proposed in [6] based on Genetic algorithms considers the problem of extracting the largest image regions that satisfy uniformity test in the intensity-spatial domain.

2. Traditional edge detectors

An edge defined in an image as a boundary or contour at which a significant change occurs in some physical aspect of the image. Edge detection is a method as significant as threshold. Four different edge detector operators are examined and it is shown that the Sobel edge detector provides very thick and sometimes very inaccurate edges, especially when applied to noisy images. The LoG operator provides slightly better results.

Traditional edge detectors were based on a rather small 3x3 neighborhood, which only examined each pixel's nearest neighbor. This may work well but due to the size of the neighborhood that is being examined, there are limitations to the accuracy of the final edge. These local neighborhoods will only detect local discontinuities, and it is possible that this may cause 'false' edges to be extracted. A more powerful approach is to use a set of first or second difference operators based on neighborhoods having a range of sizes (e.g. increasing by factors of 2) and combine their outputs, so that discontinuities can be detected at many different scales.

Edges can be detected in many ways such as Laplacian Roberts, Sobel and gradient. In both intensity and color, linear operators can detect edges through the use of masks that represent the 'ideal' edge steps in various directions. They can also detect lines and curves in much the same way.

Gradient operators, Laplacian operators, and zero-crossing operators are usually used for edge detection. The gradient operators compute some quantity related to the magnitude of the slope of the underlying image gray tone intensity surface of which the observed image pixel values are noisy discretized samples. The Laplacian operators compute some quantity related to the Laplacian of the underlying image gray tone intensity surface. The zero-crossing operators determine whether or not the digital Laplacian or the estimated second direction derivative has a zero-crossing within the pixel.

There are many ways to perform edge detection. However, the most may be grouped into three categories, gradient (Approximations of the first derivative), Laplacian (Zero crossing detectors) and Image approximation algorithms.

Edge detectors based on gradient concept are the Sobel, Roberts and Prewit Fig. 2 (b), 2 (c), 2 (d) show the effect of these filters on the remote sensing images. The major drawback of such an operator in segmentation is the fact that determining the actual location of the edge, slope turnovers point, is difficult. A more effective operator is the Laplacian Fig. 2 (d), which uses the second derivative in determining the edge.

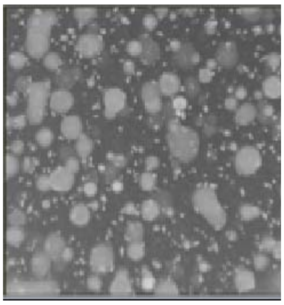


Fig. 1 colony image

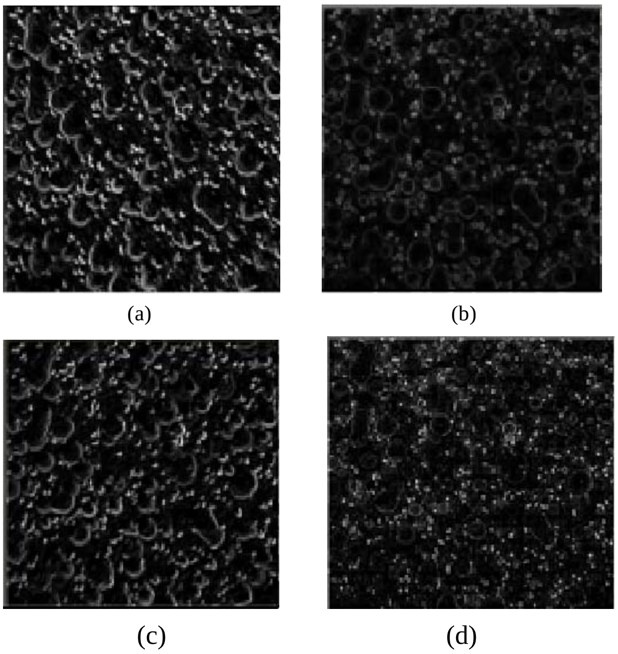


Fig. 2 (a) Edge map using Sobel operator (b) Edge map using Roberts operator (c) Edge map using Prewitt operator (d) Edge map using Laplace operator

The gradient of an image f(x, y) at location (x, y) is defined as the vector

$$\nabla f = \begin{bmatrix} G_x \\ G_y \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix} \qquad (1)$$

and the magnitude and direction of the gradient are:

$$G = \sqrt{G_x^2 + G_y^2} \quad (2)$$

where the angle is measured with respect to the x-axis. The direction of an edge at (x, y) is perpendicular to the direction of the gradient vector at that point.

3. Canny edge detection of colony image

The Canny edge detector [2] is based on computing the squared gradient magnitude. Local maxima of the gradient magnitude that are above some threshold are then identified as edges. This threshold local peak detection method is called non-maximum suppression, or NMS. The motivation for Canny's edge operator was to derive an "optimal" operator in the sense that minimizes the probability of multiply detecting an edge, minimizes the probability of failing to detect an edge and minimizes the distance of the reported edge from the true edge.

The first two of these criteria address the issue of detection, that is, given that an edge is present will the edge detector find that edge (and no other edges). The third criterion addresses the issue of localization, which is how accurately the position of an edge is reported. There is a tradeoff between detection and localization -- the more accurate the detector the less accurate the localization and vice-versa.

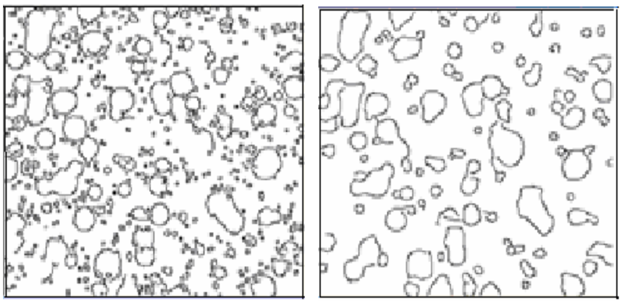
The objective function was designed to achieve the following optimization constraints:

(i) Maximize the signal to noise ratio to give perfect detection. This favours the marking of true positives.

(ii) Achieve perfect localization to accurately mark edges.

(iii) Minimize the number of responses to a single edge. This favours the identification of true negatives, that is, non-edges are not marked.

These criteria seem to be reasonable candidates for filters comparison. Fig. 3 shows a comparison between edge maps using different Canny edge detector



(a) (b)

Fig. 3 (a) Edge map using Canny operator which sigma is 0.6 (b) Edge map using Canny operator which sigma is 2.4

4. An application of GAs to edge detection of colony image

Detection of the edge in the colony image with randomness is very difficult and important task. A method proposed in [7] using genetic algorithms formulate the edge detection problem as a combinatorial optimization problem and detection of the edge is executed according to the variance of texture feature in the local area. First, we elect the candidate edge regions and then apply GAs in order to decide the optimum edge regions. This method using GAs has an advantage that arrangement of the edge regions is fulfilled by very simple architecture and it does not need much processing time.

The genetic algorithm used to find the best weighting parameters may be sketched as follows:

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Set up a random population of chromosomes $P(0) = \{\prod_1(0), \prod_2(0), \ldots, \prod_m(0)\}; t \leftarrow 0;$

Initialize $\prod_b$ with the value of the best chromosome in $P(0)$;

While t<G

for each $\prod_i(t) \in P(t)$ evaluate $f(\prod_i(t))$;

find the best chromosome $\prod_b(t) \in P(t)$;

if $f(\prod_b(t)) \geq f(\prod_b)$ then $\prod_b \leftarrow \prod_b(t)$;

Apply crossover and mutation to the current population *P*(t), according to crossover probability (pc) and mutation probability (pm);
Apply binary tournament selection to the temporary population
Obtained from the previous instruction;
$t \leftarrow t+1$;
end

Give an input image, I (i, j), of size n × m. The genetic chromosome $\alpha_{i,j}$ is coded by a 32 bit binary string that codes the pixel-label, λ in the 8 less significant bits and the pixel position (i, j) in the 24 most significant bits. Here, λ identifies the clusters to which the pixel belongs. Each chromosome can be denoted with the ordered pair $\eta(X,Y)=(X(\lambda),Y(k))$, where, $\lambda = X^{-1}(\eta)$ and the pixel in position $(i,j)\equiv Y^{-1}(\eta)$. Each segment P_j is characterized by the mean value, mv_j, of the gray levels:

$$mv_j = \frac{\sum_{\delta\in P_j} I\left(X^{-1}(\eta)\right)}{\left|P_j\right|} \quad (3)$$

The fitness function:

$$f(\eta)=\rho\left(\eta, mv_{X^{-1}(\eta)}\right) \quad (4)$$

The similarity function, ρ, computed between a given chromosome $\eta(X,Y)$ and the corresponding segment P_λ.
The classical single point crossover with bit mutation has been used to evolve the system. Random labels are assigned to the starting population of chromosomes.
The genetic operator and the selection process are applied until a halting condition which is based on the convergence of the total variance ($V_{r_t} = \sum_k^K \sigma_t(k)$) is satisfied:
Halt computation if $\left|V_{r_{t-1}} - V_{r_t}\right| \le \varepsilon$, where, $\sigma_t(k)$ is the internal variance of the cluster *k* at the iteration *t* and $\varepsilon \ge 0$, value of ε is determined by the heuristics $\varepsilon \approx \sqrt{\min\left(V_{r_{t-1}}, V_{r_t}\right)}$. The condition $\varepsilon = 0$ is not usually reached.

The edge detection result shows in Fig.4.

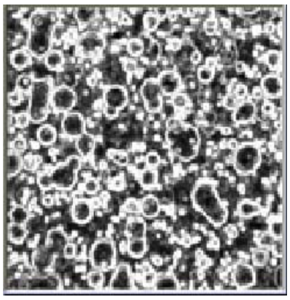

Fig. 4 Edge map using GAs edge detector for Fig.1

5. Comparison for Canny and GAs edge detection of colony images

The Canny operator works in a multi-stage process. First of all the image is smoothed by Gaussian convolution. Then a simple 2-D first derivative operator is applied to the smoothed image to highlight regions of the image with high first spatial derivatives. Edges give rise to ridges in the gradient magnitude image. The algorithm then tracks along the top of these ridges and sets to zero all pixels that are not actually on the ridge top so as to give a thin line in the output, a process known as non-maximal suppression. The tracking process exhibits hysteresis controlled by two thresholds: *TI* and T2 with *TI* > *T2*. Tracking can only begin at a point on a ridge higher than *TI*. Tracking then continues in both directions out from that point until the height of the ridge falls below T2. This hysteresis helps to ensure that noisy edges are not broken up into multiple edge fragments.

Comparing to Canny edge detection method, the edge detection method using GAs has some features as follows:

(i) It is effective to the edge detection for the texture image with randomness because of not using the pixel data but using the local texture feature, and the arrangement of the edge regions is accomplished based on the simple idea that the shortest individual within the candidate edge regions is the optimum edge regions.

(ii) To decrease and eliminate noise of the colony images, it should increase the value of Canny edge detector. But for the edge detection method using GAs, it should increase the length of the initial population.

(iii) The processing time of this method is a little more than that of the Canny edge detection method.

6. Conclusions and future work

Traditional edge detectors methods such as Roberts Cross, the Sobel Operator and Prewitt operator failed to perform adequately in such applications due to the noisy nature of remotely sensed data. They are not able to detect the edges of the object while removing all the noise in the image.

The implemented Canny edge detector presented the best performance both visually and quantitatively based on the measures such as mean square distance, error edge map and signal to noise ratio. Using the implemented Canny edge detector as an enhancement tool for remote sensing images, the result was robust and achieved a very high enhancement level.

The advantage of the edge detection method using GAs is intelligent. It is effective to the edge detection for the colony image with randomness because of not using the pixel data but using the local texture feature, and the arrangement of the edge regions is accomplished based on the simple idea that the shortest individual within the candidate edge regions is the optimum edge regions.

The future work is to decrease the processing time of the edge detection method using GAs.

Acknowledgment

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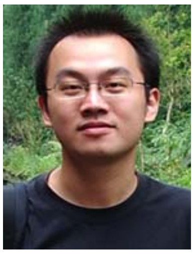

Wang Luo received the B.S. degrees in Jiangxi University of science and technology in 2003. During 2003-2005, he worked in Jinggangshan University to teach and research. He is now a student of School of Electronic Engineering University of Electronic Science and Technology of China to achieve the M.S. degree. His research interest is image processing.