

Edge Detection of Images Based on Improved Sobel Operator and Genetic Algorithms

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Abstract— Edge detection of images is a classical problem in computer vision and image processing. The key of edge detection is the choice of threshold; the choice of threshold directly determines the results of edge detection. How to automatically determine an optimal threshold is one of difficult points of edge detection. In this paper, Sobel edge detection operator and its improved algorithm are first discussed in term of optimal thresholding. Then based on Genetic Algorithms and improved Sobel operator, a new automatic threshold algorithm for images processing is proposed. Finally, the edge detection experiments of two real images are conducted by means of two algorithms. The comparative experiment results show that the new algorithm of automatic threshold is very effective. The results are also better than the classical Otsu methods.

Keywords— Edge Detection; Sobel Operator; Genetic Algorithms; Classes Square Error; Image Processing

I. INTRODUCTION

A very important goal of computer image analysis and processing is to generate some particular images that are more suitable for people or machines to observe and identify. Image edges are the most basic features of an image. The so-called image edge refers to the most prominent part of partial intensity changes in images. The edges that exist on between the main objectives and goals, objectives and background, regional and regional (including different colours), are the important basis of image analysis and processing such as the image segmentation, texture and shape characteristics. Edge detection is one of the most basic tasks in digital image processing and pattern recognition. The edge extraction and detection plays an important role in image processing. The merits of its algorithms directly affect the system performance.

How to quickly and accurately extract the edge information of the images always is a hot research topic. Our predecessors have developed a number of edge detection algorithms. Sobel operator is one of the classic algorithms [1]. The key of classical edge detection algorithm is the choice of threshold; threshold directly determines the success of edge detection. How to automatically get the best threshold of edge has been one of the difficulties of edge detection. If the selected threshold is too low, it will not only generate false edges, but edges are very thick; these edges will need to be refined again and the locations of the reprocessed edges are often not precise enough. If the threshold is too high, then many of the

edges may not be detected or the detected edges are too segmented. At present, many people use the maximum entropy method [2], Otsu threshold segmentation methods [3], [4] to achieve good results. There are still some shortcomings such as big computational complexity and low computational efficiency in these methods. In this paper, a maximum variance method between the classes based on a genetic algorithm and improved Sobel operator is presented to automatically determine the threshold. The experiment results proved that the threshold chose is suitable and effective.

The organization of this paper is as follows. In section 2, the classic Sobel edge detection operator and its improved Sobel edge detection operator are discussed. In the section 3, the basic Otsu algorithm is introduced. In section 4, a new algorithm based on genetic algorithm and improved Sobel operator is presented. In the section 5, two experiments are examined. Finally, the conclusions are stated in section 6.

II. SOBEL EDGE DETECTION OPERATOR

A. Classic Sobel edge detection operator

The Sobel operator is widely used in image processing, particularly within edge detection algorithms. Technically, it is a discrete differentiation operator, computing an approximation of the gradient of the image intensity function. At each point in the image, the result of the Sobel operator is either the corresponding gradient vector or the norm of this vector. Sobel operator is the partial derivative of $f(x, y)$ as the central computing 3×3 neighbourhood at x, y direction. In order to suppress noise, a certain weight is correspondingly increased on the centre point, and its digital gradient approximation equations may describe as follows:

$$G_x = \{f(x+1, y-1) + 2f(x+1, y) + f(x+1, y+1)\} - \{f(x-1, y-1) + 2f(x-1, y) + f(x-1, y+1)\} \quad (1)$$

$$G_y = \{f(x-1, y+1) + 2f(x, y+1) + f(x+1, y+1)\} - \{f(x-1, y-1) + 2f(x, y-1) + f(x+1, y-1)\} \quad (2)$$

Generally, the size of its gradient:

$$g(x, y) = \sqrt{G_x^2 + G_y^2} \quad (3)$$

Can also adopt similar to that:

$$g(x, y) = |G_x| + |G_y| \quad (4)$$

Its convolution template operator as follows:

$$T_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \quad T_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

If we use Sobel operator to detect the edge of image M, then we can use the horizontal template T_x and vertical template T_y to convolute with the image, without taking into account the border conditions, may get the same size of two gradient Matrix M1 and M2 as the original image. Then the total gradient value G may get by adding the two gradient matrices. Finally, we can get the edge by threshold method.

B. Improved Sobel edge detection operator

The Sobel operator is based on convolving the image with a small, separable, and integer valued filter in horizontal and vertical direction. It is relatively inexpensive in terms of computations. On the other hand, the gradient approximation which it produces is relatively crude, in particular for high frequency variations in the image.

As we know, since only the two directions of templates are used, it can only detect the edges of horizontal and vertical direction. Therefore, the edge detection of this algorithm is ineffective for complicated texture images. To compensate for Sobel's shortcomings: to make the operators more accurately describe the image edge points, to reduce the impact of noise on detection, four directions of the size of 5×5 template $T_x, T_y, T_{45}, T_{135}$ are used. The weight of every template location is determined by the distance of the location to the centre as well as the location directions. The equidistant points have the same weight. These templates are as follows.

$$T_x = \begin{bmatrix} 2 & 3 & 0 & -3 & -2 \\ 3 & 4 & 0 & -4 & -3 \\ 6 & 6 & 0 & -6 & -6 \\ 3 & 4 & 0 & -4 & -3 \\ 2 & 3 & 0 & -3 & -2 \end{bmatrix} \quad T_y = \begin{bmatrix} 2 & 3 & 6 & 3 & 2 \\ 3 & 4 & 6 & 4 & 3 \\ 0 & 0 & 0 & 0 & 0 \\ -3 & -4 & -6 & -4 & -3 \\ -2 & -3 & -6 & -3 & -2 \end{bmatrix}$$

$$T_{45} = \begin{bmatrix} 0 & -2 & -3 & -2 & -6 \\ 2 & 0 & -4 & -6 & -2 \\ 3 & 4 & 0 & -4 & -3 \\ 2 & 6 & 4 & 0 & -2 \\ 6 & 2 & 3 & 2 & 0 \end{bmatrix} \quad T_{135} = \begin{bmatrix} -6 & -2 & -3 & -2 & 0 \\ -2 & -6 & -4 & 0 & 2 \\ -3 & -4 & 0 & 4 & 2 \\ -2 & 0 & 4 & 6 & 2 \\ 0 & 2 & 3 & 2 & 6 \end{bmatrix}$$

In this algorithm, we selected the gradient value of template with the highest output as the intensity gradient of edge pixels.

III. OTSU ALGORITHM

There are many threshold selection methods. Depending on the scope of applications, the threshold methods can be divided into the 1) overall threshold method, 2) local threshold and 3) dynamic threshold method. In this paper, GA-based edge detection belongs to the overall Otsu threshold method.

Suppose $f(x, y)$ is the objective image that we want to segment, its gray range is $\{0, 1, \dots, L-1\}$. The image pixels will be divided into two categories by threshold t : $C0 = \{0,$

$1, \dots, t\}$, $C1 = \{t+1, t+2, \dots, L-1\}$. $C0$ and $C1$ respectively represent the target and background. The Classes square error between $C0$ and $C1$ as follows:

$$\sigma(t)^2 = \omega_0(t) * \overline{\omega}_1(t) * (\mu_0(t) - \mu_1(t))^2 \quad (5)$$

Here t is that threshold, $\omega_0(t)$ is the number of pixels in which gray value of its image are less than the threshold t . $\overline{\omega}_1(t)$ is the number of pixels in which the image gray value are greater than the threshold value t . $\mu_0(t)$ is the average gray value of the pixels in which the image gray value are less than the threshold t . And $\mu_1(t)$ is the average gray value of the pixels in which the image gray values are greater than the threshold t . The t that makes $\sigma(t)^2$ the greatest value is the best partition threshold. Here the best threshold required needs to traverse all the pixel gray values within the scope and calculate the variance and finally arrive at the greatest variance. It is obvious that the calculation cost is huge and the efficiency of calculation is also low; determining the optimal threshold is ultimately an optimization problem. A genetic algorithm that is adopted must greatly improve the computational efficiency.

IV. ALGORITHM DETAIL

The new algorithm mainly includes three steps as follows.

1) Get the gradient image by using the previous four directions templates to calculate the image point by point.

2) Resolve the best partition threshold of the gradient image by Otsu method based on genetic algorithms. This algorithm consists of six steps as follows.

(1) Chromosome encoding:

Encode chromosome into an 8 bit of binary string to denote a threshold.

(2) Population initialization:

Randomly generates 40 chromosomes as the initial population.

(3) Design of fitness function

Refers to the maximum classes variance $\sigma(t)^2$ as the fitness function

(4) Crossover operator:

Use single-point crossover method, crossover probability is 0.9.

(5) Mutation operator:

Experimental results show that the stability of solution is good when the mutation probability of a GA is very small. But the solution once drops in a local extremum, it is hard to come out, and results in a big probability of premature convergence. If the mutation probability achieved much, genetic algorithm will degrade as a random search. To enhance the algorithm performance, in this paper, an adaptive mutation rate P_m is adopted as follows.

$$P_m = \begin{cases} 0.1, \frac{f_{\max} - f}{f_{\max} - \bar{f}} > 1 \\ 0.002, \frac{f_{\max} - f}{f_{\max} - \bar{f}} < 1 \end{cases} \quad (6)$$

In formula (6), f_{\max} is the maximum value of fitness function in current population. \bar{f} is the mean fitness. f indicates the fitness function of the individual that have mutated.

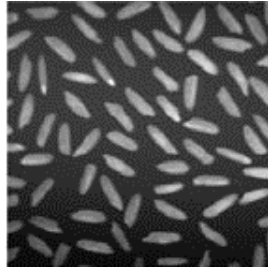
(6) The algorithm termination and post-treatment:

Take the highest individual fitness and decode to get the best threshold after 50 times of iterative calculations.

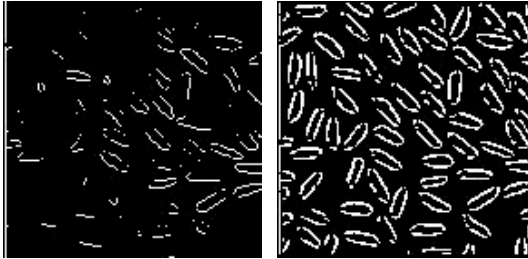
3) According to the threshold, if the image gray value is greater than or equal to the threshold, you can determine the point as the initial edge point, and the direction of that point is the direction of the edge point, otherwise is a non-edge points.

V. RESULTS

In order to test the effectiveness of this algorithm, we used the default algorithms in MATLAB and the new GA based algorithm presented in this paper to compare the edge detection results of images. Figure 1 and figure 2 are the experiment results of two experiments. The size of original image (a1) is a 142 * 142 pixel of rice image. The size of original image (a2) is a 338 * 350 pixel of cells image with noise. Figure b1, c1, b2, and c2 are respectively the detected results of the two images by using the default MATLAB algorithms and the new algorithm.



(a1) Rice Image



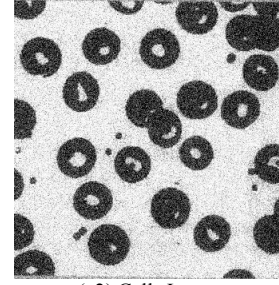
(b1) Sobel Detection (c1) New Detection

Fig. 1 edge detection results of rice image

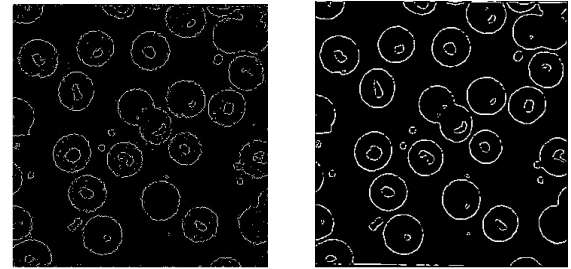
Comparing the two results b1 and c1 of edge detection of image (a1), we can easily find that the new algorithm that used improved detection template and GA got better result than the traditional Sobel operator. The new algorithm has stronger edge search capability and more complete edge. Image (a2) test with noise shows that the new algorithm has anti-noise ability, may overcome the shortcomings of Sobel operator that is extremely sensitive to noise.

Table 1 is the experiment results of running time of two algorithms. The average time is an average value of ten times detection of 338 * 350 images. Because the new algorithm

combines the advantages of the genetic algorithm and the traditional two-dimensional Otsu methods, the computation cost of new algorithm has been improved. The running time of two algorithms has obvious difference. This may be easily found from the data 1.5s and 0.92s in table 1. The efficiency increases 38.7 %.



(a2) Cells Image



(b2) Sobel Detection

(c2) New Detection

Fig. 2 edge detection results of cells image

TABLE I
ALGORITHM RUNNING TIME

Methods	The average time
Otsu Method	1.5s
New method	0.92s

VI. CONCLUSIONS

To sum up, this paper used improved Sobel operator and genetic algorithms to optimize segmentation threshold of gradient image and proposed a new automatic optimal threshold algorithm. The new algorithm overcame many shortcomings of classical Sobel operators such as over-segmentation and sensitivity. Comparative experiment results show that the calculation speed and anti-noise capability of the new algorithms gets stronger. However, we may also find the detected edges are not fine enough, and a better refining operator will be developed in the future.

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