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Study on Improved Algorithm for Image Edge Detection Based on Genetic Fuzzy

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Abstract

Aiming at the existing edge detection algorithm of edge vague, the pseudo-edge cannot be removed and algorithm results do not achieve optimal results by virtue. In order to improve the reliability and effectiveness of edge detection, the proposed optimization tool template coefficient method, to design the coding, Sobel filter and fitness function of genetic fuzzy clustering algorithm. Through interpolating, smooth handling and filtering with the updated active contour model. Based on the traditional edge detection algorithm is analyzed, combined with fuzzy membership functions and genetic operators for edge detection algorithm was improved by genetic fuzzy clustering. Through the simulation results showed that this new algorithm was feasible. Theoretical analysis and experimental results demonstrate that, the new algorithm in this paper is highly antinoise and able to get better image edges.

Keywords: *Image Processing, Genetic Algorithms, Fuzzy Clustering, Edge Detection, Fuzzy Membership Functions*

1. Introduction

Edge is the most basic feature of images, which includes the most part information of images [1]. Edge detection is widely used in image analysis and processing such as feature description, image segmentation, image enhancement and pattern recognition *etc*, and has turned into a hot spot in research on image processing and analysis technology [2]. Edge detection is an important part of image processing; it is also the foundation of image analysis. Find the actual border line of the target image corresponding to the true edge; it has been a hot topic in the field of image processing [3].So far, many algorithms have been presented in edge detection field [4]. Despite all this, the edge detection of digital image has not been fully solved. But still it is the major challenge in image processing to improve the accuracy and the signal-to-noise ratio of edge detection algorithm [5]. This is because the traditional edge detection algorithm is based on gradient differential; there are different degrees of limitations of these algorithms [6]. It is the major challenge in image processing to improve the accuracy and the signal-to-noise ratio of edge detection algorithm, thus making the algorithm an emphasis of professional study.

Genetic algorithm is search algorithm by learning natural selection and random genetic mechanisms biosphere, and it is a global optimization search algorithm, which has simple, universal, robust, and suitable for parallel processing features [7].

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People did a lot of researches in how to use genetic algorithm to the image edge detection, but the majority of these studies were unfolded by classical edge detection algorithm. The presence of these algorithms cause considerable disadvantage that edge positioning accuracy and scale edge detection problem is a contradiction [8]; another traditional edge detection algorithm is also necessary to set a threshold value to distinguish noise point and edge point [9],but how to customize setting the optimal threshold adaptation is difficulty; Moreover, in different applications, people want to achieve different objectives, and therefore different definitions of edge and object edges. It is difficult to find a universal edge detection algorithm.

There are many kinds of ways to detect the edge [10]. Anyway, there are two main techniques: one is classic method based on the gray grade of every pixel, which is got the longest research, get the edge according to the variety of the pixel gray. The main techniques are Robert, Laplace, Sobel, Canny and LOG algorithm [11].The other one is based on wavelet and its multi-scale characteristic, which is based on wavelet transform, utilizes the Lipschitz exponent characterization of the noise and singular signal and then achieve the goal of removing noise and distilling the real edge lines. In recent years, an improved haze removal algorithm reference [12], which presents Genetic algorithm for design optimization of multimode dynamics using differential–algebraic equation integrators. The edge is easy to find in frequency domain. It’s a reliable method.

In the usual situation, we may the signal in singular point and the point of discontinuity thought is in the image peripheral point, its nearby gradation change situation may reflect from its neighboring picture element gradation distribution gradient. According to this characteristic [13], we proposed many kinds of edge examination operator: If Robert operator, Sobel operator, Prewitt operator, Laplace operator and so on. These methods many are waiting for the processing picture element to carry on the gradation analysis for the central neighborhood achievement the foundation realized and has already obtained the good processing effect to the image edge extraction [14]. But this kind of method simultaneously also exists has the edge picture element width, the noise jamming is serious and so on the shortcomings, even if uses some auxiliary methods to perform the denoising, also corresponding can bring the flaw which the edge fuzzy and so on overcomes with difficulty [15]. In the multitudinous scientific research worker under, has obtained the very good effect diligently. But, because the image edge receives physical condition and so on the illumination influences quite to be big above, often enables many to have a common shortcoming based on brightness edge detection method, that is the edge is not continual, does not seal up.

Considered genetic algorithm in the image importance as well as its stable characteristic, it causes using the genetic fuzzy clustering algorithm to carry on the imagery processing into new research topic [16]. Image edge detection which is based on genetic algorithm, as a research subject has its practical significance and theoretical significance. Based on genetic fuzzy clustering algorithm solves the traditional edge detection algorithm shortcomings, this article from the perspective of optimizing the image edge extraction analysis.

2. Genetic Fuzzy Clustering Algorithm

Edge detection is a terminology in image processing and computer vision, particularly in the areas of feature detection and feature extraction, to refer to algorithms which aim at identifying points in a digital image at which the image brightness changes sharply or more formally has discontinuities. Although point and line detection certainly are important in any discussion on segmentation, edge detection is by far the most common approach for detecting meaningful dis-counties in gray level [17].

The idea of genetic algorithm (GA) is derived from the existence and evolution of living creatures in nature, which is a kind of bionic algorithm in macro sense, and it follows evolutionary theory of Darwinand genetic variation theory of Mendel, if we understand the nature of species selection and optimization in the environment, we can simulate this process to complete the optimization of the objective function. GA is a random search and optimization process based on the simulation of biological evolution.

GA simulates the evolutionary process of nature, and the genetic algorithm uses a representative problem to simulate the natural population [18]. The population is made up of individual genes. Individual is the individual representative of the nature of biological groups. The chromosome determines the individual character, that is, the external performance of the fitness. In the algorithm, there are a certain number of individual populations, using random selection to select a certain number of individuals, genetic cross, in order to imitate the genetic information exchange. And randomly select a certain number of individuals, in a random position to make the gene mutation. According to the principle of survival of the fittest, assess each individual's ability to adapt, to generate new population [19]. Such iterative iteration to find the solution to the problem, that is, the highest degree of adaptation presents the individual representative of the solution.

An Improved used algorithm to handle the problem of appropriate thresholds for threshold is by using threshold with hysteresis. This algorithm uses multiple thresholds to find edges [20]. We begin by using the upper threshold to find the start of an edge. Once we have a start point, we then trace the path of the edge through the image pixel by pixel, marking an edge whenever we are above the lower threshold. We stop marking our edge only when the value falls below our lower threshold. This approach makes the assumption that edges are likely to be in continuous curves, and allows us to follow a faint section of an edge we have previously seen, without meaning that every noisy pixel in the image is marked down as an edge. We can come to a conclusion that, to be classified as a meaningful edge point, the transition in gray level associated with that point has to be significantly stronger than the background at that point. Since we are dealing with local computations, the method of choice to determine whether a value is “significant” or not. Thus we define a point in an image as being as being an edge point if its two-dimensional first-order derivative is greater than a specified criterion of connectedness is by definition an edge.

The edge detection problem of the image can be transformed into a function optimization, so it can be optimized by using genetic algorithm [21]. First, genetic algorithm is used to optimize the existing edge detection template, according to the specific problem design optimization parameters, through interpolating , smooth handling and filtering with the updated active contour model, and finally to achieve the best edge detection effect: next, it can be set up appropriate fitness function to search edge by using genetic algorithm directly on the image , so as to avoid the template scale and positioning accuracy of the selection problem; moreover, genetic algorithm is used to search the best edge detection threshold, adaptive threshold edge detection algorithm is set to lay the foundation.

3. Improved Algorithm Based on Genetic Fuzzy Clustering

Edges are places in the image with strong intensity contrast. Since edges often occur at image locations representing object boundaries, edge detection is extensively used in image segmentation when we want to divide the image into areas corresponding to different objects. Representing an image by its edges has the further advantage that the amount of data is reduced significantly while retaining most of the image information.

3.1. The Improved Edge Template

The operation usually outputs two images, one estimating the local edge gradient magnitude and one estimating the edge orientation of the input image. When using improved edge template the image is convolved with a set of (in general 8) convolution kernels, each of which is sensitive to edges in a different orientation. For each pixel the local edge gradient magnitude is estimated with the maximum response of all 8 kernels at this pixel location:

$$|G| = \max(|G_i : i = 1 \quad to \quad n|) \tag{1}$$

Where, G_i is the response of the kernel i at the particular pixel position, and n is the number of convolution kernels. The local edge orientation is estimated with the orientation of the kernel that yields the maximum response. The whole set of 8 kernels is produced by taking one of the kernels and rotating its coefficients circularly. Each of the resulting kernels is sensitive to an edge orientation ranging from *0°* to *315°* in steps of *45°*,where *0°* corresponds to a vertical edge.

The maximum response $|G|$ for each pixel is the value of the corresponding pixel in the output magnitude image. The values for the output orientation image lie between 1 and 8, depending on which of the 8 kernels produced the maximum response. An edge template is matched to the image, each representing an edge in a certain orientation. The edge magnitude and orientation of a pixel is then determined by the template that matches the local area of the pixel the best.

3.2. Coding Design

Genetic algorithm is to iterate, search, optimization operations in genetic space, so the solution space coding is an important step. Encoding method used by data types can be divided into binary code and real-coded. Binary encoding is the solution space mapping in place on the string space B^l = {0, 1}, that is, the solution space for any variables are used to represent the binary string. Binary encoding process must first determine the length of the bit string, which is the first agreement with several binary strings to represent a variable.For grayscale digital image 256, each pixel gray values are encoded, the bit string length is 8, one of the binary strings ($b_7b_6b_5b_4b_3b_2b_1b_0$),(b_i=0 or 1,i=0,1...7) corresponds to [0, 255] of a value. For any optimization problem, the solution space can be mapped to [0, 1], this mapping is the definition of domain normalized.

Definition: normalization real number encoding is encoded in the [0, 1] interval. It is evolved from the binary code. The gene is digital, it has (0 ~ 9) 10 possible values.

By definition, the normalized real-coded is decimal coding essence. The coding length is one of the important parameters that affect the normalization of real-coded, which determines the method is as follows: To solve the accuracy $\varepsilon=10^{-m}$, the domain of $x\in [a, b]$ one-dimensional optimization problem, so $x_{\max}=\max\{|a|, |b|\}$, then the code length L is:

$$L \geq \text{int}(\lg x_{\max}) + l + m \tag{2}$$

Where int(x) represents the function of rounding the variable x, m is an integer. For multidimensional space optimization problem, the same calculation method of encoding length, except that the $x_{\max}$ values different ways: First, for each dimension of the absolute value of the maximum value of the variable, and then select the greatest in the selected value, it is $x_{\max}$ values.

If domain set up a one-dimensional optimization problem is $x\in [a, b]$, the normalized real-coded formulas and corresponding decoding formula are as follows:

$$x^* = \frac{x-a}{b-a} \tag{3}$$

$$x = \frac{b-a}{x^*} + a \tag{4}$$

Normalized coding advantages: the solution space variables mapped to [0, 1], so that the real number coding has been standardized, not only facilitate data processing, and easy to carry out the theoretical analysis of the problem; normalized real-coded for easy selection, crossover such as genetic manipulation, genetic operators higher search efficiency.

3.3. Fitness Function Design

Since edges consist of mainly high frequencies, we can, in theory, detect edges by applying a high-pass frequency filter in the Fourier domain or by convolving the image with an appropriate kernel in the spatial domain. In practice, edge detection is performed in the spatial domain, because it is computationally less expensive and often yields better results

For specific optimization problems, there are two possible scenarios, one is very small that the smaller the value of individual adaptation of the original performance as possible; the second is that the larger the very large-scale adaptation of the original value of individual performance better. However, the fitness function of genetic algorithm generally require non-negative, and the greater the degree of individual performance to adapt better, which necessarily requires the original fitness function appropriately converted into a standard measure in a way that are all very large, and the fitness of non-negative. For very small, its standardized fitness is generally defined as follows:

$$f_{normal}(x) = f_{\max}(x) - f(x) \tag{5}$$

Where, $f_{\max}$ is an upper bound $f(x)$ of the original function. If $f_{\max}$ is unknown, it can be artificially set a larger constant instead of $f_{\max}$, so this constant make $f_{\text{normal}}(x) \geq 0$ permanent establishment. For very large, its standardized fitness is generally defined as:

$$f_{normal}(x) = f(x) - f_{\min}(x) \tag{6}$$

Where, $f_{\min}$ is the original function of a lower bound $f(x)$. If $f_{\min}$ is unknown, it can be artificially set to replace a smaller constant $f_{\min}$, so this constant make $f_{\text{normal}}(x) \geq 0$ permanent establishment.

3.4. Genetic Operators Design

Genetic operators include selection operator, crossover operator and mutation operator. The existing research shows that when the population size is relatively small, the diversity of population is not necessary. And when a large population size, the group internal diversity makes it unnecessary to search for more patterns, using point crossover can make the algorithm faster, higher search efficiency. The fit degree of the cross mentioned above is suitable for the two kinds of situations, but the amount of calculation is obvious.

Binary-coded mutation operator is based on a certain probability P_m, the mutation probability) will be selected to take the counter, which is 0 to 1, 1 to 0. The mutation operator of real encoding is more complex than the binary encoding, and the common mutation operator design method includes two kinds of point type variation and uniform variation. Point mutation randomly choose a variant in a parent string, and then take a random number in [0,9] .Since the main purpose of the variation is to broaden your search solution to prevent falling into local optimal solution, so the real number coding variation in the integer part of multiple-choice position.

3.5. Fuzzy Sets and Fuzzy Membership Functions

Image processing has three main stages: image fuzzification, modification of membership values, and, if necessary. The fuzzification and defuzzification steps are due to the fact that we do not possess fuzzy hardware. Therefore, the coding of image data and decoding of the results are steps that make possible to process images with fuzzy techniques. The main power of image processing is modification of membership values [22]. Gradient direction gives the direction of maximal growth of the function, such as from black ($f(x, y)$ =0) to white ($f(x, y)$ =255). This is illustrated below: closed lines are lines of the same brightness.

The values of the edge map are normalized to the interval of 0 and 1 to represent the edginess membership values. The system implementation was carried out considering that the input image and the output image obtained after defuzzification are both 8-bit quantized; this way, their gray levels are always between 0 and 255. The fuzzy sets were created to represent each variable's intensities; these sets were associated to the linguistic variables "Black", Edge and "white". The adopted membership functions for the fuzzy sets associated to the input and to the output were triangles, as shown in Figure.1.

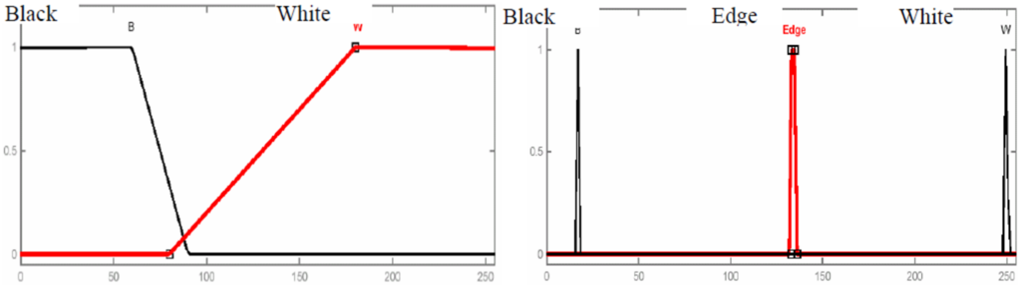


Figure 1. Membership Functions of the Fuzzy Sets Associated

3.6. Sobel Filter Design

Edges are pixels where brightness function changes abruptly. We can describe changes of continuous functions using derivatives. Brightness function depends on two variables co-ordinates in the image plane and so operators describing edges are expressed using partial derivatives [23]. Most edge detection methods work on the assumption that the edge occurs where there is a discontinuity in the intensity function or a very steep intensity gradient in the image. Using this assumption, if one take the derivative of the intensity value across the image and find points where the derivative is maximum, then the edge could be located. The gradient is a vector, whose components measure how rapid pixel value are changing with distance in the x and y direction. Thus, the components of the gradient may be found using the following approximation [24]:

$$\frac{\partial f(x,y)}{\partial x} = \Delta x = \frac{f(x+dx,y) - f(x,y)}{dx} \tag{7}$$

$$\frac{\partial f(x,y)}{\partial x} = \Delta y = \frac{f(x,y+dy) - f(x,y)}{dy} \tag{8}$$

Where, dx and dy measure distance along the x and y directions respectively. In discrete images, one can consider dx and dy in terms of numbers of pixel between two points. $dx = dy = 1$ (pixel spacing) is the point at which pixel coordinates are(i, j) thus,

$$\Delta x = f(i+1, j) - f(i, j) \tag{9}$$

$$\Delta y = f(i, j+1) - f(i, j) \tag{10}$$

In order to detect the presence of a gradient discontinuity, one could calculate the change in the gradient at (i, j) .This can be done by finding the following magnitude measure

$$M = (\Delta x^2 + \Delta y^2)^{0.5} \tag{11}$$

And the gradient direction is given by

$$\theta = \tan^{-1}\left|\frac{\Delta y}{\Delta x}\right| \tag{12}$$

The Laplacian method searches for zero crossings in the second derivative of the image to find edges. The gradient method detects the edges by looking for the maximum and minimum in the first derivative of the image. As shown in Figure.2.

(a) Input Image

(b) The Laplacian Method

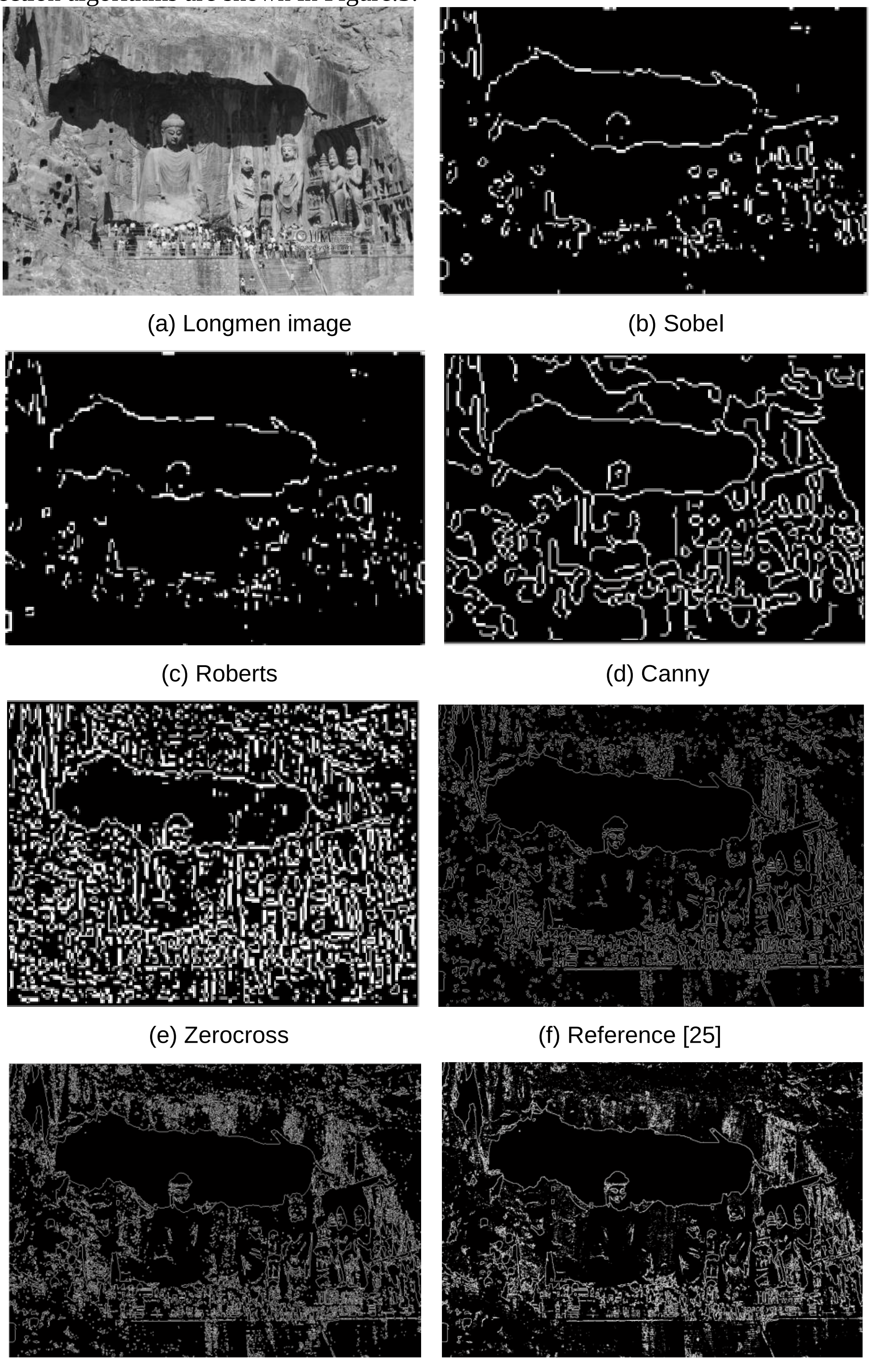
(c) The Gradient Method

(d) The Solebl Method

Figure 2. Experimental Results

4. Experimental Results and Analysis

In order to verify the effectiveness of the edge detection algorithm, this paper made a lot of experiments, the proposed algorithm was tested with different images, its performance being compared to that of classical algorithm (Sobel, Roberts, Canny and Zerocross operator) and a possibility fuzzy c-means clustering algorithm proposed in reference [25], Kernel-based fast improved possibility c-means clustering method in reference [26]. The edge detection based on classical algorithm using the image processing toolbox in MATLAB is illustrated; the comparison results of different edge detection algorithms are shown in Figure.3.



(a) Longmen image (b) Sobel

(c) Roberts (d) Canny

(e) Zerocross (f) Reference [25]

(g) Reference [26] (h) New Algorithm

Figure 3. The Comparison Results of Different Edge Detection Algorithms

As shown in Figure.3, the original Longmen image is shown in Figure.3 (a). Edge detection result by Sobel operator is shown in Figure.3 (b), the edge detection is not continuous, Noise immunity is poor. The result of edge detection by Roberts's operator is shown in Figure.3(c), edge thick and relatively smooth, but lost a lot of detail edge, such as Little Buddha. There is obviously some noise left on the edge map and some of the edges are corrupted. It is company together between edges and noise by Canny, which is shown in Figure.3 (d). There is a phenomenon of false edges by Zerocross operator which is shown in Figure.3 (e).Edge detection is relatively results by reference [25] and reference [26], which are shown in Figure.3 (f) and Figure.3 (g). It can extract most of the edges, but details are not clear. By applying the new algorithm based on genetic fuzzy clustering on the image to detect its edges, it is found that the modified version of edge map has less noise and less edge corruption as shown on the image of Figure.3 (h), a thin edge is better because we only want to preserve the edge rather than the details in the neighborhood. The resulting images of our fuzzy technique seem to be much smoother with less noise in the flat areas and sharper in the edgy regions than the conventional algorithm.

We can get the following summary, does not have in the noise situation in the image, the Prewitt operator, the Robert operator, the Sobel operator as well as the differential gradient operator, all can the quite accurate examination edge. But, after joins the white Gaussian noise, the Robert operator receives the influence is smallest, next is the Prewitt operator, receives affects in a big way is the Sobel operator, but regarding the differential gradient operator, then is the image overall contrast gradient has obvious depression. The LOG operator always can produce the false edge. After adding on the noise, traditional examination algorithm the examination quality dropped obviously. But the new algorithm examination result is continuously extremely satisfying. By comparing the experimental results, it can be seen in this paper, a new algorithm for better positioning accuracy of the extracted edge line more detailed, which shows the effectiveness of the new algorithm.

5. Conclusion

The image edge detection is the key part of image processing. Classical edge detections always have different localization. This paper proposes an edge detection algorithm based on genetic fuzzy clustering analysis. The algorithm makes use of the great ability of optimization tool template coefficient method, which overcomes sensitivity to initialization of fuzzy clustering method and fixes on the numbers of clustering as well as the center s of clustering dynamically. Through interpolating, smooth handling and filtering with the updated active contour model. Based on the traditional edge detection algorithm is analyzed, combined with optimization tool template coefficient optimization method for edge detection algorithm was improved by genetic fuzzy clustering. The application of the algorithm proposed to image edge detection and comparative experiments show that the algorithm has great ability of detection the fuzzy edge and exiguous edge. And also evidently restrain the degenerating phenomenon during the evolutionary process, which indicates it is outstanding and bio-simulation method.

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