Variable Length Niche Algorithm and Application in Fuzzy Image Edge Detection

Jie Zhang, Jiali Tang, Honghui Fan

School of Computer Engineering, Jiangsu University of Technology, Changzhou 213001, Jiangsu, China

Abstract
The image edge detection is the point that the obvious change of the brightness in the digital image is marked, and the information not related is removed, and the important attribute of the image is preserved. The traditional edge detection algorithm uses the Gauss filter algorithm, and the edge detection of the fuzzy image is not good. A fuzzy edge detection algorithm based on the variable length niche algorithm is proposed in this paper. Fuzzy image edge detection of the tentor space model is established. In tensor space with 4 layer Morlet wavelet decomposition method for processing of image feature extraction and the noise reduction filter, to extract the image pixel feature of variable length coding, to simulate the properties of biological evolution, the punishment which adapt to small valves of individuals, by variable length coding and niche algorithm of redundant information out, effectively ability is insufficient problem. Simulation results show that the proposed method has the highest PSNR value, and the edge of the image is the best, which has better connectivity and color difference.
Key words: IMAGE; EDGE DETECTION; NICHE ALGORITHM

1. Introduction

With the development of computer digital image processing technology, image processing algorithms are widely used in target identification, geological exploration, remote sensing detection, remote detection and fault diagnosis field, and some other fields. The associated image processing algorithms including image fusion, image noise reduction, edge detection and image filtering method. Among them, edge detection is a fundamental problem in image processing and computer vision. By identifying significant changes in the brightness of the digital image contour points, the edge detection realized continuous tracking of image highlights, excluded the irrelevant information, and retained the important structural properties of the image. In view of this, image edge detection has important applications in image recognition and feature extraction [1].

The conventional method of image edge detection mainly including Gaussian filter method, wavelet transform edge detection method, and edge detection algorithm which based on bionic algorithm [2-4]. With the development of niche (microhabitat) technology, the application of niche technology in image edge detection is derivative and expansion of edge detection algorithm which based on bionic algorithm. Niche is a concept from biology, it refers to a living environment under specific environments, and simulate the property of biological evolution. It makes each generation of individual in evolutionary computation divided into a number of categories, by hybridization and mutation to produce a new generation of groups of individual and punish the individuals which have small adaptive value, to achieve optimal clustering and feature detection [5]. Therefor, it is feasible to use niche algorithm for image edge detection. In this paper, for the ineffective fuzzy image edge detection in using Gaussian filtering algorithm, a kind of fuzzy edge detection algorithm based on variable-length niche algorithm is proposed. First, construct tensor space model of fuzzy image edge detection. Second, 4-layer Morlet wavelet decomposition method is used in tensor space for image feature extraction and noise reduction filtering. Then variable-length coding the extracted image pixel characteristic and use niche algorithm to improve image edge detection algorithm. At last, simulation experiments were performed to verify the performance, showing the superior performance of proposed algorithm in image fuzzy edge detection.

2. Tensor Model and Feature Extraction of Image Edge Detection

2.1 Tensor model in fuzzy image edge detection

Edge detection is the basic problem in image processing and computer vision. In the implementation of edge detection, the primary issue is to build tensor feature space, make the identification digital image light up in tensor space, and realized continuous tracking and property tags of two points in the image. Tensor is a characteristic vector which defined in some vector space [6]. Set gray scale image f, for any pixel (x, y), Using tensor space of second-order characteristic vector to describe the characteristic information of each fuzzy image pixels. In tensor space, by describing the image light-up model and image degradation process to get an image tensor space that can be represented as a 2×2 matrix, as follows:

$$\mathbf{T} = \begin{pmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{pmatrix} \quad (1)$$

The figure model structure of fuzzy image $G=(V,E)$ is divided into a normalized scale-center distance collection A and B. With $A\bigcup B = V$, $A\bigcap B = \phi$, state equation of image segmentation features as follows:

$$I(x) = J(x)t(x) + A(1-t(x)) \quad (2)$$

Where: $I(x)$ is the intensity of the original image, $J(x)$ is the superpixel light intensity of fuzzy image. The image edge detection problem is solving eigenvalues problem of above tensor model space model, that is $\mathbf{T}-(\lambda\mathbf{I})e = 0$. The edge of two-phase flow from fuzzy image grouped into two molecules sets: $C_1, C_2 \subseteq V$. The eigenvalues are λ_1 and λ_2 ($\lambda_1 \geq \lambda_2$), the segmentation scale of reference image is 1, highest scale is M, and the main characteristics direction of image edge portrayed by e_1, iterative recursion formula of image tensor space contraction as follows:

$$d_{i+1} = 2F(x_{i+1} + \frac{1}{2}, y_i + 2) = \begin{cases} 2[\Delta x(y_i+2) - \Delta y(x_{i,r} + \frac{1}{2} - \Delta xB)] & d_i \leq 0 \\ 2[\Delta x(y_i+2) - \Delta y(x_{i,r} + 1 + \frac{1}{2} - \Delta xB)] & d_i > 0 \end{cases} \quad (3)$$

For any second-order two-dimensional symmetric definite tensor, regional differences in edge detection is the maximum weight value of image pixels, constraint parameters can be described as:

$$h = \theta/\pi,\ s = 1 - \frac{\lambda_2}{\lambda_1},\ v = \lambda_1 + \lambda_2 \quad (4)$$

Where: θ is the main direction angle of ellipse in tensor space, λ_1, λ_2 is long and short semiaxis length of image edge detection. According to the above parameter model to construct HSV color space, local neighborhood domain is $B(x, y)$, consider the image two-dimensional feature $F: E \to R^3$ in domain E, let $\mathbf{T}: E \to \mathrm{PDS}(2)$. Information tensor space model of fuzzy image shown in Figure 1.

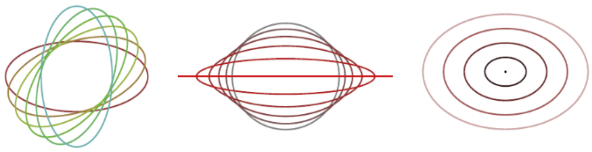


Figure 1. Information tensor space of fuzzy image

Figure 1 shows that, in processing of image edge detection, the edge features of reference image and the image to be matched can uniquely identify an ellipse. Pixel features discontinuities in depth, as the impact of changes in scene illumination, by finding the image second derivative zero crossing to find the boundary in tensor space, then realize edge detection. However, the simple edge detection algorithm interference by uncertainty factors such as noise, so it requires the use of variable length coding and niche algorithm for image coding and filtering process to improve the performance of image edge detection.

2.2 Extraction of Image Features and Pretreatment of Denoise Filtering

On the base of image tensor space construction and feature analysis, we extracted the image feature and reduced the noise to improve the capacity of edge detection and image recognition feature. Image is a visual reflection of real objects and describes how it is reflected in the relevant information. However, the noise is a form of prejudice hinder its accuracy, it prevents the human visual organ and image sensing system for accurate receiving and analyzing the image[7]. In this paper, four layers Morlet wavelet decomposition method used for image feature extraction and denoise filtering, $\psi(t)$ is the mother wavelet of 4 layers Morlet wavelet, the continuous transform is:

$$W_{\psi} y(a,b) = < y, \psi_{a,b} > = \int_{-\infty}^{+\infty} y(t) \frac{1}{\sqrt{|a|}} \psi^{*} (\frac{t-b}{a}) dt \tag{5}$$

Morlet wavelet function family $\psi_{a,b}$ was supported by a following affine transformation:

$$\psi_{a,b}(t) = [U(a,b)\psi(t)] = \frac{1}{\sqrt{|a|}} \psi(\frac{t-b}{a}) \tag{6}$$

Morlet wavelet select the set of edges $A \in E$, and consider the degree of coupling between the sub-graph, so:

$$b_m = t_0(1-a) \tag{7}$$

Then,

$$f_{i_a}(t) = f_i(t+b_m) \tag{8}$$

In the image filtering, by wavelet transformation matrix make the image digitization, including sampling point set of images and digital quantization. Assume that the image is $w(a, b)$, acquisition of digital matrix is permutation and combination form of $c*d$. Then, the digital image matrix is represented as $w(a, b)$. Its image digitized pixel value is expressed as a formula:

$$w(a,b) \rightarrow \begin{bmatrix} w(a_1,b_1) & w(a_1,b_2) & \dots & w(a_1,b_d) \\ w(a_2,b_1) & w(a_1,b_2) & \dots & w(a_1,b_d) \\ \vdots & \vdots & \ddots & \vdots \\ w(a_c,b_1) & w(a_c,b_2) & \dots & w(a_c,b_d) \end{bmatrix} \rightarrow \tag{9}$$

$$[w(i,j)]_{c*d}$$

De-noising through four layers Morlet wavelet image decomposition model. When the noise operator of image is P_j, then the general form of de-noising model is:

$$P_j(w)(a) = \int_{\Omega} u(a,b)w(b)pb \tag{10}$$

Function $\tau(C)$ is used to control difference between the two regions C_1 and C_2, the above-mentioned matrix array represents the digital image information and the size of digital image determines the number of array. In the matrix, digital elements of array and pixels of the image are corresponding, which stores the gray values of image pixel. Significant changes of image property usually reflect the important events and changes in properties. Therefore, in the processing of image feature extraction and filtering, we need to retain the image of two important edge information[8]. Through the above processing, realizing the image feature extraction and pretreatment of denoise filtering, to offer clean image feature data for the subsequent edge detection algorithm.

3. Improvement of Variable Length Niche Algorithm and Fuzzy Image Edge Detection Algorithm

3.1 Proposed the Variable Length Niche Algorithm

Based on the above image feature extraction and noise reduction filtering, we improved the fuzzy image edge detection. Niche is a concept from Biology. It refers to, under a particular kind of living environment, we simulate the properties of biological evolution, and divide each generation of individuals in the evolutionary computation into several categories, then hybridization and variation to produce a new individual generation, and punish the individual which has smaller fitness. We using the idea of variable-length coding, and encoding for the four layers Morlet wavelet features to improve the accuracy of edge detection. In the image tensor space, assuming that the initial scale of target image pixel value is a ($a<1$), then get the reference image and the image to be matched variable length coding phase are:

$$I_l(n_1,n_2) = \frac{1}{4}\sum_{i_1=0}^{1}\sum_{i_2=0}^{1} I_{l-1}(2n_1+i_1, 2n_2+i_2) \tag{11}$$

$$J_l(n_1,n_2) = \frac{1}{4}\sum_{i_1=0}^{1}\sum_{i_2=0}^{1} J_{l-1}(2n_1+i_1, 2n_2+i_2) \tag{12}$$

In a 7 × 7 pixel matching window, using Niche Algorithm fitting an anti-harmonic interference vector. Due to telescopic changes in the time scale equivalent to the translation in time, thereby realizing the variable length coding for image pixel characteristic. Then, the Niche Algorithm can be expressed as: Niche individual mapped to each point of the image feature point in search space, in the processing of optimization, niche individual behavior as the objective function.

In image area which selected the reference point as the center to construct a phase correlation function, so get the niche evolution of objective function:

$$W_u u(a,b_m)=\frac{1}{\sqrt{a}}\int_{-T/2}^{T/2}u(t)u^*(\frac{t-b_m}{a})dt$$
$$=\frac{1}{\sqrt{a}}\int_{-aT/2+b_m}^{T/2}u(t)u*(t)dt=\frac{1}{\sqrt{a}}\int_{-aT/2+b_m}^{T/2}\left|u(t)\right|^2dt$$

(13)

Among them, at the point of (a,b_m) in scale panning plane, niche optimal solution represents a two-dimensional image edge features. In hence, with variable length niche algorithm can improve the accuracy of image edge detection.

3.2 Implement of Fuzzy Image Edge Detection

In the fuzzy image edge detection, when the Hamming distance between two individuals less than the pre-specified value l (also called niche distance), punish the individual that has smaller fitness value. The location of niche individuals describe the survival of the fittest of no amount of noise individuals, and at different frequencies search image false contour feature points. With the movement of niche biological position, all individuals gradually moving from the inferior position to the optimum position and guide the search. You can get the two-dimensional characteristic in spectral function, calculate the $R(k_1,k_2)$,we get:

$$R(k_1,k_2)=\frac{F(k_1,k_2)\overline{G(k_1,k_2)}}{\left|F(k_1,k_2)\overline{G(k_1,k_2)}\right|}=e^{j\theta(k_1,k_2)} \qquad (14)$$

By calculating the zero uniform traversal features and logic variable differential scale features in objective function, we obtained the partial derivatives of Center v_i. Then make derivative equals zero, we got global searching of fuzzy membership degree and iterative clustering center by efficient Niche algorithm. Update the expression is:

$$u_{ik}=\left\{1-\left[1-\frac{(d_{ki}^2+\beta d_{\bar{k}i}^2)^{-1/m-1}}{\sum_{j=1}^{c}(d_{kj}^2+\beta d_{\bar{k}j}^2)^{-1/m-1}}\right]^{\alpha}\right\}^{1/\alpha} \qquad (15)$$

$$v_i=\frac{\sum_{k=1}^{n}(1-(1-u_{ik}{}^{\alpha})^{1/\alpha})^m(x_k+\beta\overline{x_k})}{(1+\beta)\sum_{k=1}^{n}(1-(1-u_{ik}{}^{\alpha})^{1/\alpha})^m} \qquad (16)$$

In the above formula, $u_{ik}{}^{\alpha}$ is the diversity factor, β is fuzzy membership matrix and d_{ki}^2 is the parameters of the image edge detection neighborhood information. By the above arrangement, obtain the cross-correlation function in the evolution of niche fuzzy image. If the two images are completely dissimilar, then return, and if the pixels are similar, then conduct the next space tensor of image edge detection until the algorithm convergence, thereby realizing the image fuzzy edge detection.

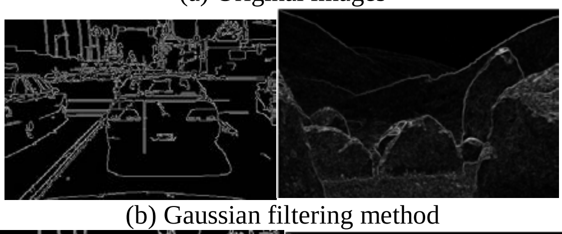
4. Simulation and Analysis of Results

To validate the algorithm performance in image fuzzy edge detection, the hardware environment of simulation experiment is: computer with Pentium(R) D, IntelCoreZ 2.4 GHz CPU and 2GB memory, using Matlab 7 as a simulation software for data programming and algorithms. First, collect the original data of the fuzzy image, image acquisition is a 1meter resolution panchromatic sensor, and the image pixels are $a_1=(0.4,0.9,0.9)$, $a_2=(0.6,0.7,0.6)$, on the basis of it, design the tensor space then get second-order tensor coefficients are:

$$\mathbf{A}_1=\begin{pmatrix}0.1521 & 0.2164\\ 0.2164 & 0.7479\end{pmatrix},\ \mathbf{A}_2=\begin{pmatrix}0.1693 & -0.0949\\ -0.0949 & 0.4307\end{pmatrix}$$

The size of niche population is 30, the hybrid probability is 0.32, the punishment probability is 0.42 for the individuals which have small fitness values, and mutation probability is 0.09. Based on the above parameters, conduct image edge detection simulation, and get the results shown in Figure 2. In it, capture images of two different scenarios original images were given, one is the edge detection outputs results which using the traditional methods, the other one get from the method in this paper.

(a) Original images



(b) Gaussian filtering method

(c) Method in this paper

Figure 2. Image fuzzy edge detection results

From the figure 2, we can see that using the method in this paper for image edge detection, image has better wire connectivity and color consistency in tensor space. While traditional methods are difficult to take the relationship between the color classification into account, so the capture performance is not very well. The proposed method uses four layers Morlet wavelet decomposition method for image feature extraction and noise reduction filtering, and eliminate redundant information characteristics by the variable length coding and niche algorithm, effectively overcome the traditional method of boundary information extraction problem. In order to quantitatively analyze the performance of the algorithm, using different algorithms (peak signal to noise ratio PSNR as the test indicators) to obtain comparative results shown in Figure 3. We can see that when using the method in this paper, it has highest PSNR value, which means performance of image edge detection and image quality both are the best.

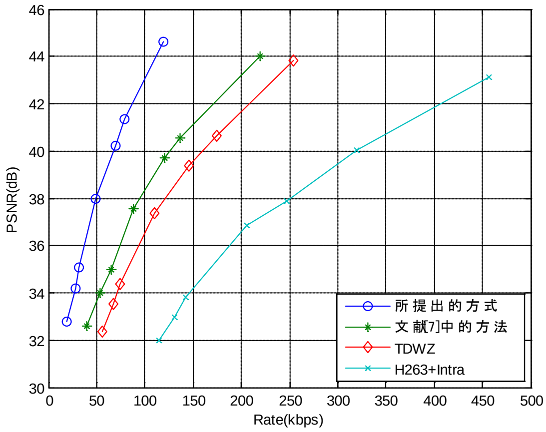


Figure 3. Analysis of range detection performance with PSNR

5. Conclusion

In this paper, the fuzzy image edge detection method was researched. The image edge detection is accomplished by identifying the obvious brightness variation point in digital image, removing irrelevant information, and retain the important attributes of the image, to enhance the image recognition ability. However, the traditional edge detection algorithm uses Gaussian filtering algorithm for edge detection fuzzy image is not good. A new variable length niche algorithm was presented in this paper. First of all, construct tensor space model of fuzzy image edge detection, then use four layers Morlet wavelet decomposition method for image feature extraction and noise reduction filtering process in tensor space, and variable length encoding the image pixel features, at last, improve the image edge detection algorithm which based on niche algorithm. The results show that using the method in this paper, it has highest PSNR value, which means performance of image edge detection and image quality both are the best, and has better wire connectivity and color consistency.

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