The PCNN adaptive segmentation algorithm based on visual perception

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ABSTRACT

To solve network adaptive parameter determination problem of the pulse coupled neural network (PCNN), and improve the image segmentation results in image segmentation. The PCNN adaptive segmentation algorithm based on visual perception of information is proposed. Based on the image information of visual perception and Gabor mathematical model of Optic nerve cells receptive field, the algorithm determines adaptively the receptive field of each pixel of the image. And determines adaptively the network parameters W, M, and β of PCNN by the Gabor mathematical model, which can overcome the problem of traditional PCNN parameter determination in the field of image segmentation. Experimental results show that the proposed algorithm can improve the region connectivity and edge regularity of segmentation image. And also show the PCNN of visual perception information for segmentation image of advantage.

Keywords: Image segmentation; pulse coupled neural network; Gabor; visual perception information; region connectivity; adaptive parameter determination

1. INTRODUCTION

Image segmentation denotes a process which a raw image is partitioned into no overlapping regions based on the consistency and similarity of certain features in the same region and greater difference in the different region. The image segmentation problem is treated as a key issue of comprehension and analysis of image. Image segmentation algorithm at this stage is divided into three categories, including algorithm based on region, algorithm based on edge and the algorithm based on mathematical morphology. The algorithms have achieved good segmentation results, but the common shortcomings of algorithms are the strong pertinence and the poor universality. The research and evaluation system of image segmentation is no unified theory system. It is the new direction of the image segmentation to find a new universal image segmentation algorithm, which has Adaptability of the iImage characteristics.

In 1990, Eckhorn et al proposed a neural network model based on the cat's visual cortex nerve signal conduction characteristics [1]; 1999, Johnson improved the model as suitable for image processing, which was called the PCNN [2]. The model can be successfully applied to image segmentation as new segmentation research direction. Application of image segmentation of PCNN can be roughly divided into two categories, the first algorithm is based on the segmentation rules and PCNN applications [3][4]; the second is based on PCNN parameter determination and algorithm improvements, which became main research methods. Kuntimad G [5] proposed Perfect Image Segmentation Using Pulse Coupled Neural Networks by the parameter of β . Min Li proposed Adaptive Parameters Determination Method of Pulse Coupled Neural Network Based on Water Valley Area. the algorithm use dynamic threshold of image to replace dynamic threshold of PCNN,which achieve multi-gray level image segmentation. Yuli Chen proposed a new automatic Parameter Setting Method of a Simplified PCNN for Image Segmentation, which successfully determine all adjustable parameters based on the statistical characteristics of the image. Yangna proposed algorithm of vehicle image segmentation based on RF'PCNN model, which successfully determine connection matrix parameters based on receptive field. Yan chuman, Guo baolong,Ma yide proposed new adaptive algorithm for image segmentation using the dual level PCNN model, Which achieve parameter adaptive settings and adaptive segmentation of the image based on regional growth theory. The obvious advantage of the PCNN in image segmentation is decided by its biological basis. But the model has many network parameters, and the parameters setting are very difficult, the setting determines the reasonable segmentation and algorithm applications. Therefore, the development of the regional character of PCNN and adaptive

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parameters determination of PCNN segmentation algorithm has practical importance. The algorithm has good segmentation results and the universality.

2. THEORY AND ALGORITHM

2.1 Pulse coupled neural network model

Figure 1 shows neuron model which Eckhorn proposed [1]. Neurons cell is made of the feedback input field, the coupling of the input field and the pulse generator.

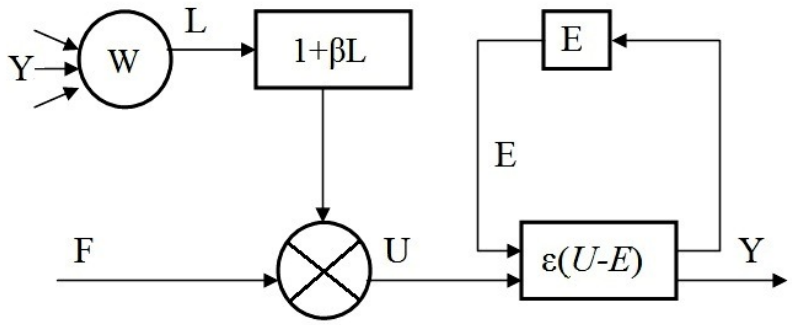

Figure 1.The neurons structure of traditional PCNN

The following discrete system model is described by the iterative difference equation style.

$$F_{ij}(n) = e^{-\alpha_F} F_{ij}(n-1) + V_F \sum_{kl} M_{ijkl} Y_{kl}(n-1) + S_{ij} \tag{1}$$

$$L_{ij}(n) = e^{-\alpha_L} L_{ij}(n-1) V_L \sum_{kl} W_{ijkl} Y_{kl}(n-1) \tag{2}$$

$$U_{ij}(n) = F_{ij}(n)(1 + \beta L_{ij}(n)) \tag{3}$$

$$Y_{ij} = \begin{cases} 1 & U_{ij}(n) > E_{ij}(n-1) \\ 0 & others \end{cases} \tag{4}$$

$$\mathrm{E}_{ij}(n) = e^{-\alpha_E} E_{ij}(n-1) + V^E Yi_j(n) \tag{5}$$

S_{ij} is the value of the gray value of the input image or the transformation. F_{ij}, L_{ij}, U_{ij} and Y_{ij} correspond to the feedback input, coupled input, internal activity item and neuronal cell output of (i, j) neurons cell. M_{ijkl}, W_{ijkl} is the matrix of connection coefficient. is connection strength coefficient of the nerve synapse. α_F and V_F, α_L, and the V_L, α_E and V_E correspond to the amplification factor and the decay time of the feedback domain, the amplification factor of the coupling domain and the decay time, decay coefficient of E_{ij} and the dynamic threshold inherent EMF.

Internal activity items (U_{ij})is built by nonlinear modulation of feedback input field and coupled input field , When Uij> E_{ij}, the neuron cell is fired ,immediately increases the dynamic threshold, then the threshold decays exponentially, until neuron cell is again fired. By the formula (1) (2) (3), the value of the internal activity is decided by the parameter values of W, M and β, and decided the ignition timing. The parameters of W, M are that how neighborhood neurons affect central neurons. It reflects the neighborhood neurons pass to the strength of the information of the center neurons. The literature at this stage generally believed that the connection coefficient matrix W and M have the same rule, and set the same value in the experiment. The parameter β is directly related to the value of M and W. Thus, the research key of this article is adaptive set PCNN parameters by the visual information of the image and visual perception model.

2.2 Visual perception

Plan of "ten years of the brain" promoted multi-level, interdisciplinary research to the advanced functions and its neural mechanism of the brain, and make the subject into the focus of scientific research in the 21st century [10]. Compared with the other information, Brain processing of visual information occupies the main position in brain external accepted information. One of the key visual perception theories includes the scope, content and calculation model of the optic nerve cells. The receptive field of optic nerve cells combines the content, scope and calculation model, and gives the computational model of visual perception theory.

2.3 Optic receptive field and calculation model

Receptive field is the region reflected the stimulation of visual neurons cell. In addition to glial cells, the all visual cells in the visual system have receptive fields, or have behalf of the receptive field of the cell in the retina.

John Daugman studies the spatial vision by information theory, and extends the one-dimensional Gabor to two-dimensional. Gabor function is a modulation of the cosines or sine of Gaussian function. Two-dimensional Gabor function can be adjusted by the scale and direction to describe the receptive fields of the spatial properties of primary cortex simple and complex cell. Two-dimensional Gabor function is expressed as

$$h(x,y) = g(x',y')[\cos(2\pi f_0 x') + j\sin(2\pi f_0 y')] \tag{6}$$

The parameter θ is the orientation of the Gabor filter, f_0 is center frequency, $\sigma_x and \sigma_y$ is the Gaussian variance in the airspace x 'and y' direction.

2.4 The Algorithm of PCNN parameters setting

Receptive field reveal the response of the optic nerve cells to external stimuli. Different cortical nerve cells have different receptive field and receptive content. Optic nerve cells in the same layer have selectivity to feel content. The receptive field content of primary visual cortical cell include simple visual features (such as orientation, position, color, etc.), as well as some simple texture and shape cues. A characteristic of the processing of advanced cerebral cortex nerve cells is obviously complex. The content of senior cortical cells receptive field is made of a simple visual cell output by the neural network convergence. Therefore, the receptive fields of simple cells are basis, which research the optic nerve receptive field.

PCNN network connectivity matrixes of W and M reveal relations of center neurons and the surrounding neurons. And reveal the relation of local area of the image center pixel and neighborhood pixel in image processing. If the center pixel was viewed as the optic nerve cells, the values of M and W are set adaptively by receptive field of the cell. The adaptive setting of PCNN model parameters can be realized by the image's visual perception information, and the model has biological visual features.

The Gabor function is viewed as receptive field model of visual neurons. The 2D Gabor of multi-directional and multi-scale corresponds to the optic nerve cell receptive field of the selectivity and directionality. Therefore, the proposed algorithm steps are given.

Step1. The Neighborhood Space *R* is decomposed into low frequency and high frequency sub-band images by applying multi-scale and multi-direction of Gabor transform, which is formed by the image point $I(x,y)$, and the energy coefficient of all sub-bands is calculated according to equation (7) and (8).

$$E(s,\theta) = \frac{\sum A_{gabor}{}^2(s,\theta)}{m \times n} \tag{7}$$

$$\lambda(s,\theta) = \frac{E(s,\theta)}{\sum E(s,\theta)} \tag{8}$$

The size of the neighborhood space R is m and n. A and B denote the energy response and amplitude of Gabor transform, s and θ respectively correspond to the scale and direction of Gabor function, the $E(s,\theta)$ is the energy of sub-band images based on the parameter of s and θ .

Step2. Energy coefficients vector is arranged in descending. The size of parameter M is determined based on the Gabor size of the maximum energy response coefficient. The front effective elements of the vector are selected by the

experimental requirements and the values of effective elements are assigned to the elements of the matrix M, the direction of matrix elements correspond to the angle θ of coefficient. The other elements of the matrix are assigned zero.

Step3.the value of β is calculated according to equation (9),the value of E_0 is selected and calculated according to literature.

$$\beta = \frac{\sum \lambda(s,\theta)}{M \times N} \tag{9}$$

3. EXPERIMENTAL RESULTS AND DISCUSSION

The algorithm reliability is tested by Lena image and synthetic artificial image, then Compare experimental results with the classic Otsu method .The result of Lena image segmentation is evaluated by the subjective method. the result of artificial image segmentation is evaluated by the objective method. The experimental environment is Matlab7.012 64-bit version, 2G frequency of the CPU (dual-core), 4G main memory and win7 64-bit version.

3.1 The segment result of the Lena image and Analysis

The structure of Lena image contains much information, such as the piecewise smooth regional and texture. Therefore it is widely used to compare image segmentation algorithms. The experimental results are as follows.

Figure 2.segmentation results of Lena image based on Otsu method and the proposed method. The left column is the original image, the middle is result by Otsu method, and the right is result by the proposed method.

The experiments confirmed that, compared with the classical algorithm, the proposed algorithm achieved good segmentation results, Too small and undesired discrete spot areas is almost eliminated in the Lena image segmentation. The region connectivity and edge regularity of segmentation image is improved.

3.2 The segmentation result of the artificial image and Analysis

To test the effect of the proposed algorithm segmentation reliability, 512X512 synthetic image is selected to complete the multi-region segmentation test. Experimental evaluation criteria are Mistakable Classification Rate (MCR).it is defined as.

$$MCR = \frac{MCP}{APTM} \tag{10}$$

MCP is the total number of mistakable classification pixels in the region. ATMP is the total number of pixels in the region. The MCR value is the smaller; the segmentation algorithm is the stronger. The segmentation results and evaluation table are as follows.

Figure 3. Segmentation results of artificial image based on the proposed method. The left column is the original image, the middle is label result, and the right is result by the proposed method.

Comparison of the original image, segmentation result by the classic PCNN model and the proposed method, the Difference can not be distinguished between the original image and the result of the proposed algorithm through the subjective evaluation. Therefore the proposed algorithm has better segmentation results.

Table 1.Segmentation results for artificial image

Area	Original PCNN MCR	Proposed method MCR
1	0.97	0.02
2	0.92	0.05
3	0.00	0.00
4	0.00	0.00
5	0.42	0.00
6	0.79	0.00
7	0.00	0.00
8	0.00	0.00

Compared with classical PCNN segmentation algorithm, number of mistakable classification pixels is little, and the pixels only exist on the regions boundary (e.g., region 1 and region 2 boundary), the value of MCR is low; there are not mistakable classification pixels in the other regions. The proposed algorithm obtains better segmentation results on the artificial image segmentation.

4. CONCLUSION

The proposed algorithms achieved the adaptive PCNN key parameters settings and avoided the network parameter settings difficult problem, which based on image itself information and the biological visual perception theory and Gabor model of optic nerve cells. Algorithm universality is improved. The experimental results confirmed that the proposed algorithm improved the region connectivity and edge regularity of segmentation image and accuracy of target segmentation. The algorithm boundary optimization and the algorithm application will do further research in the future.

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