Pulse Couple Neural Network Based on Visual Perception

Gai Pan¹ and Xiangyong Kong²,1,a,*

¹School of Electrical Engineering & Automation, Jiangsu Normal University, Xuzhou, Jiangsu 221116, P.R. China
²Jiangsu Normal University Kewen College, Xuzhou, Jiangsu 221116, P.R. China
Email: a kxy2006@126.com

Abstract. The traditional pulse coupled neural network model only considers the spatial position information between neurons, but neglects sensitivity of human visual perception to luminance change, especially when the brightness is high or low, the visual sensitivity of the human eye is relatively low, and in a certain range of brightness, the visual sensitivity of the human eye is relatively high, so it is easy to have false segmentation. In order to solve this problem of the traditional pulse coupled neural network model, this paper redescribes the connection weights between neurons by using the human eye luminance weight factor, and obtains the new pulse coupled neural network model based on visual perception. Through the simulation experiment of life images, experimental results show that the proposed algorithm is better than the traditional pulse coupled neural network model.

1. Introduction
Image segmentation is the basis of image processing, and the accuracy of image segmentation affects the effect of subsequent image processing. There are many image segmentation methods, among which pulse coupled neural network (PCNN) has the advantage of grouping pixels with similar gray level, reducing the local gray level difference, and making up the small discontinuity of local area, better than other automatic segmentation methods[1-4]. However, many parameters of the pulse coupled neural network model affect the segmentation effect of the PCNN model, and the selection of the optimal parameters is one of the difficulties in the image segmentation of the PCNN model, PCNN model is difficult to accurately describe the inherent relationship between neurons, which affects the segmentation effect.

In order to solve the problem of parameter setting in PCNN model, an improved cuckoo search algorithm is presented in the application of human segmentation in infrared images[5]. He et al. proposed an image segmentation algorithm based on double-layer pulse coupled neural network model for kiwifruit detection[6]. Lian et al. proposed a modified simplified pulse coupled neural network based on human visual system for medical images[7].

In order to improve the segmentation effect of the pulse coupled neural network model, experts put forward different model improvement schemes, for example: Jiang et al. got the segmentation image by each iteration through PCNN model[8], the Canny operator is used to get the boundary image of the segmented image and the segmented image. The minimal difference between the two boundary images is selected, and the corresponding segmentation image of the boundary image is the optimal segmentation effect, although a new method to select the optimal segmentation effect is given, it is not easy to generalize in image segmentation because of its large computation. Xie et al. used the segmentation effect of PCNN model as the initial contour curve, and used the improved variational level set method to segment the image target[9]. Based on the color features, Xu et al. proposed a region growing pulse coupled neural network model for color Image segmentation[10]. Guo et al.
proposed to introduce significant eigenvalues into a simplified pulse coupled neural network model for object segmentation[11].

Experts put forward different methods to improve the PCNN model[5-11], which can improve the image segmentation effect, but ignore sensitivity of human visual perception to luminance change.

2. Pulse Coupled Neural Network

According to studying the phenomenon of synchronous oscillation of neurons in cat visual cortex, Eckhorn et al. proposed the neuron model[1]; On this basis, Johnson and Padgett proposed pulse coupled neural network[2], which used neurons to construct a nonlinear dynamic neural network, with neurons interacting with each other and connecting with each other, mainly includes receptive field, linking part or modulation, and pulse generator, the mathematical formula is described as follows:

\[ f_{ij}[n] = I_{ij} \] (1)

\[ L_{ij}[n] = V_L \sum_{kl} W_{ijkl} Y_{kl}[n-1] \] (2)

\[ U_{ij}[n] = F_{ij}[n](1 + \beta L_{ij}[n]) \] (3)

\[ Y_{ij}[n] = \begin{cases} 1 & U_{ij}[n] > \theta_{ij}[n-1] \\ 0 & \text{otherwise} \end{cases} \] (4)

\[ \theta_{ij}[n] = e^{-\alpha_{ij}} \theta_{ij}[n-1] \] (5)

Where, \( n \) is iteration number; \( f_{ij} \) is the input of neuron; \( L_{ij} \) is the linking input of neuron; \( V_L \) is the amplification factor of coupling connection domain; \( W_{ijkl} \) is the inner linking matrix between neuron \( N_{ij} \) and neuron \( N_{kl} \); \( U_{ij} \) is the internal state of the neuron; \( \beta \) is the linking coefficient; \( \theta_{ij} \) is the dynamic threshold; \( \alpha_{ij} \) is the time constant; \( Y_{ij} \) is the pulse output.

In the traditional pulse coupled neural network model, the pixel is regarded as the neuron, the gray value of the pixel is regarded as the external excitation of the neuron, and the neurons in the neighborhood also produce the external excitation, when the threshold is greater than the dynamic threshold, the neuron is fired, the output is 1, when the threshold is less than the dynamic threshold, the neuron is in the inhibitory state, the output is 0, the image segmentation effect is obtained.

Compared with other automatic image segmentation algorithms, the pulse coupled neural network model can reduce the difference of local gray level, make up for the small local discontinuities, and group pixels with similar gray level in local area, however, the traditional pulse coupled neural network model only considers the position of neurons when describing the connection weights between neurons, ignoring that the brightness information of neurons can influence visual perception to a certain extent, especially when the brightness is high or low, the visual sensitivity of the human eye is relatively low, and in a certain range of brightness, the visual sensitivity of the human eye is relatively high, making the connecting weights between neurons inaccurate, it is difficult to get the ideal segmentation effect.

3. Pulse Coupled Neural Network Based on Visual Perception

3.1. Human Eye Luminance Weight Factor

To illustrate the sensitivity of human visual perception to changes in brightness, John Doe et al. proposed a background brightness sensitivity threshold curve[12-13], as shown in figure 1, the ordinate represents the perception threshold of human eye, and the abscissa represents the background luminance value. When luminance value is higher or lower, the visual sensitivity of the human eye is relatively low, and in a certain range of luminance, the human eye has a relatively high visual
sensitivity. If the sensitivity of the relatively high luminance range of human visual sensitivity is set to 1, and the other luminance range is scaled accordingly, the luminance weight factor of human eyes can be obtained as equation (6).

\[
KL_{ij} = \begin{cases} 
2.0 - 0.0133 \times f_{ij} & f_{ij} < 75 \\
0.0108 \times f_{ij} - 0.3462 & f_{ij} > 125 \\
1.0 & \text{other}
\end{cases}
\] (6)

![Figure 1. Background luminance sensitivity threshold](image)

3.2. Pulse Coupled Neural Network Based on Visual Perception

In the traditional PCNN model, \( W_{ij} \) is the inner linking matrix between neuron \( N_{ij} \) and neuron \( N_{kl} \), and \( W_{ijkl} = \begin{bmatrix} 0.707 & 1 & 0.707 \\ 1 & 0 & 1 \\ 0.707 & 1 & 0.707 \end{bmatrix} \), which only shows the spatial position information between neurons, but neglects sensitivity of human visual perception to luminance change, and it is easy to have false segmentation.

In order to solve the problem of inaccuracy in describing the connection weights between neurons in the traditional pulse coupled neural network model, the human eye luminance weighting factor, which is suitable for human eyes to perceive luminance changes, is used in this paper, the connection weights between neurons and neighbouring neurons are redescribed as follows:

\[
W'_{ijkl} = KL_{ij}
\] (7)

In the new connection weights, not only the gray information of the local area, but also the sensitivity of the luminance difference of the local area to the visual perception are considered. Bring equation (7) into equation (2) and get a new connection input \( L_{ij} \) as equation (8).

\[
L_{ij}[n] = V_i \sum_{kl} KL_{ij} Y_{kl}[n - 1]
\] (8)

4. Simulation Experiment

In order to verify the feasibility of the proposed algorithm, two kinds of image segmentation algorithms are involved in the experiment: the traditional PCNN algorithm and the proposed algorithm. The parameters of the traditional PCNN model are set to:
In the simulation experiment, figure 2.a is life images to be segmented, and life images come from 360 image database. The object to be segmented is irregular geometry shape, weak boundary, background and the gray range of the object overlap, among which figure 2.a is the image of angelica dahurica, the target is the angelica area, figure 3.a is an image of a dandelion in an all-black environment, the object is the dandelion area. Figure 2.b is image segmentation of traditional pulse coupled neural network model.

\[
\alpha = 0.1, V_c = 3, \beta = 0.1, W_{ki} = \begin{bmatrix}
0.707 & 1 & 0.707 \\
1 & 0 & 1 \\
0.707 & 1 & 0.707
\end{bmatrix}.
\]

It can be seen that the local long and thin target pixels are mistakenly segmented into background pixels, the main reason is that the gray value of the local target pixel is close to the gray value of the neighbourhood background pixel, so it is easy to be stimulated by the neighbourhood neuron when calculating the inner activity term of the neuron, and get the wrong segmentation result. Figure 2.c is the segmentation result obtained by using the pulse coupled neural network model presented in this paper. Compared with the traditional PCNN model, the false segmentation is reduced, the main reason is that the human eye luminance weight factor is used to describe the connection weights between neurons in the pulse coupled neural network model. Not only the difference of local gray values, but also the gray information of local areas are considered, the new internal activity is obtained, and the segmentation effect is better, especially for the weak boundary region. The simulation results show that the improved PCNN model is better than the traditional PCNN model.

5. Simulation Experiment
The human eye luminance weight factor, which is suitable for human eyes to perceive luminance changes, is used to describe the connection weights between neurons in the pulse coupled neural network model, a new connection input is got and the now pulse couple neural network based on visual perception is proposed. The simulation results show that the improved PCNN model is better than the traditional PCNN model.
6. Acknowledgements
This work was supported by the Natural Science Foundation of the Jiangsu Higher Education Institutions of China (Grant No. 18KJB413002) and National Natural Science Foundation of China (Grant No. 61673197).

7. References
[1] Eckhorn R., Reitboeck H., Arndt M., et al. Feature Linking via Synchronization among Distributed Assemblies: Simulations of Results from Cat Visual Cortex [J]. Neural Computation, 1990, 2(3):293-307.
[2] Johnson J. L., Padgett M. L.. PCNN models and applications [J]. IEEE Transactions on Neural Networks, 1999, 10(3):480-498.
[3] Wang Z., Ma Y., Cheng F., et al. Review of pulse-coupled neural networks [J]. Image and Vision Computing, 2010, 28(1):5-13.
[4] Monica Subashini M., Sahoo S. K.. Pulse coupled neural networks and its applications [J]. Expert Systems with Application, 2014, 41(8):3965-3974.
[5] He F., Guo Y., Gao C.. A parameter estimation method of the simple PCNN model for infrared human segmentation [J]. Optics & Laser Technology, 2019, 110:114-119.
[6] He F., Fu C., Shao H., et al. An image segmentation algorithm based on double layer pulse coupled neural network model for kiwifruit detection [J]. Computers and Electrical Engineering, 2019, 79:106466-106474.
[7] Lian J., Yang Z., Su W., et al. An image segmentation method of a modified SPCNN based on human visual system in medical images [J]. Neurocomputing, 2019, 333(14):292-306.
[8] Jiang W., Zhou H., Shen Y., et al. Image segmentation with pulse coupled neural network and canny operators [J]. Computers and Electrical Engineering, 2015, 46:528-538.
[9] Wei W., Li Y., Ma Y.. CNN-based level set method of automatic mammographic image segmentation [J]. Optic, 2016, 127:1644-1650.
[10] Xu G., Li X., Lei B., et al. Unsupervised color image segmentation with color alone feature using region growing pulse coupled neural network [J]. Neurocomputing, 2018, 306:1-16.
[11] Guo Y., Yang Z., Ma Y., et al. Saliency Motivated improved simplified PCNN model for object segmentation [J]. Neurocomputing, 2018, 275:2179-2190.
[12] Yu L., Dai F., Zhang Y., et al. Novel rate distortion optimization strategy based on perceptual properties of texture and luminance [J]. Journal of Image and Graphics, 2012, 17(1):54-61.
[13] Fei M., Peng Z., Li C., et al. Human perception features based rate distortion optimization for HEVC [J]. Journal of Image and Graphics, 2015, 20(7):857-864.