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Applications of PCNN in Medical Image Processing

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Abstract

Pulse coupled neural network (PCNN) is derived from the synchronous neuronal burst phenomena in the cat visual cortex. So it is very suitable for image processing, especially medical image. This paper discusses some methods for medical image segmentation and fusion based on PCNN. The advantages and disadvantages of PCNNs were analyzed for performing image processing in the realm of medical diagnostics.

Keywords: Pulse coupled neural network, PCNN, medical image segmentation, medical image fusion

1. Introduction

Artificial neural networks (ANN) are inspired from the idea of biological neural network having the ability to learn from inputs for processing features and for making global decisions. PCNN has a biological basis, compared with the traditional artificial neural network, and is the bionic vision of advanced mammals.

In 1990s, Eckhorn proposed the underlying model to explain the experimentally observed pulse synchrony process found in the cat visual cortex [1-3]. On the basis of its proposed structure, the general structure of PCNN is shown in Fig.1

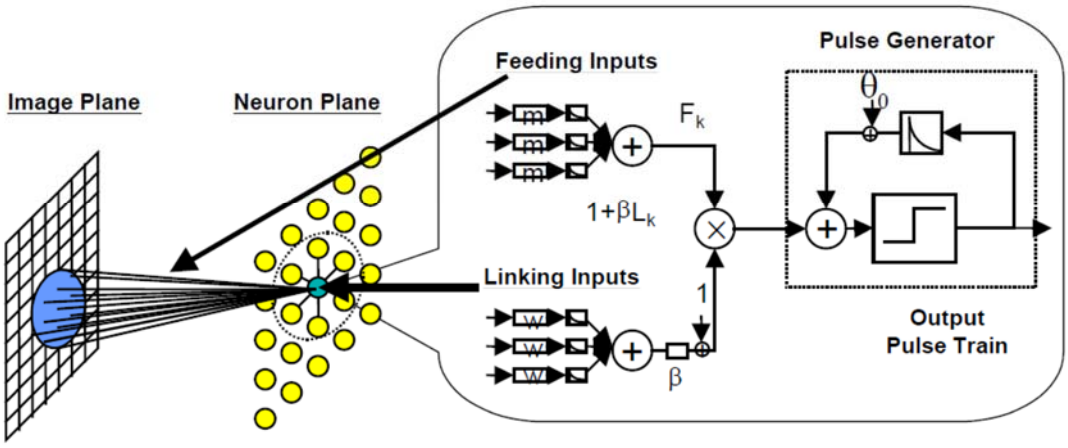

Fig.1. The general structure of PCNN

Biological systems have always been an inspiration for developing algorithms, pulse coupled neural network (PCNN) was developed and the simplified version of PCNN was intersecting cortical model (ICM) and the network is being utilized in many image processing techniques like feature extraction, image recognition and image segmentation [4-6]. PCNN model is significantly different than other

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artificial neural network models in both its structure and operation. In the PCNN model, each neuron in the processing layer is directly tied to an image pixel or set of neighboring image pixels. Each neuron iteratively processes signals feeding from these nearby image pixels (i.e., feeding inputs) and linking from nearby neurons (i.e., linking inputs) to produce a pulse train.

In the face of massive image data, different imaging modes, different application scenarios and different application purposes and other specific conditions, there has never been a method to meet all aspects of the requirements. To sum up, in many fields, image segmentation based on pulse combining neural network has broad prospects and important research value.

2. Pulse coupled neural networks and its applications

2.1. Applications in image segmentation

Image segmentation is a technique that groups pixels into regions, and therefore object regions. In segmentation processing, human supervision has greatly influence on the segmentation accuracy. So improving the performance and decrease the running time are greater concerns for a good system. PCNN overcomes most of the disadvantages if modified according the needs. Keller [7] discussed the method for MRI image segmentation based on PCNN, and the result showed that PCNNs do well at contrast enhancement. They also do well at image segmentation when each segment is approximately uniform in intensity. YZ Lin [8] used simplified PCNN for separating the cucumber from complex background. They have reduced the number of parameters in addition to the adjustment of connection strength coefficient in the pulse coupled neural network model. In recent years, the research on PCNN based image segmentation methods can be summarized as the following three aspects:

(1) Improvement or simplification of the PCNN model

There are two main ideas: one is to quantify the parameters of the PCNN network, and the other is to reduce the number of redundant iterations. By optimizing the PCNN model in these two aspects, which can reduce the running time of the system and improve the efficiency of calculation.

(2) Best segmentation image obtained by PCNN combined with the best segmentation image discriminant criterion

There are many image segmentation methods based on entropy function and PCNN, such as mutual information entropy, minimum cross entropy, etc., this combination is mainly using the characteristics of entropy function to achieve good segmentation effect. However, f the entropy function does not necessarily obtain the information in the original image, which has a negative impact on the subsequent evaluation of complex images. Therefore, we should further consider how to select the most accurate criteria in many extraction functions. In 2008, SU [9] proposed an algorithm for segmentation and counting of red blood cells based on PCNN and auto wave. The algorithm not only can segment and denoise the red blood cell image better, but also can effectively reduce the influence of other non-red blood cells in the process of counting red blood cells in the image. Experimental results show that the proposed algorithm has strong robustness.

(3) Improving the anti-noise performance of segmented images

Reducing the influence of noise on target image is always one of the important targets of digital image processing technology. Lu Yujing [10] proposed a denoising method based on simplified PCNN model aiming at the influence of speckle on the diagnosis of breast cancer ultrasound images. In this method, the simplified PCNN model to locate the extreme impulse noise points, and salt and pepper noise were removed by the PCNN and median filter. Second, the Gaussian noise by adjusting the gray value

adaptively was removed by using PCNN time matrix with category filter. This method has obvious advantages in filtering effect and detail protection, and the validity of this method has been proved by medical diagnosis.

Although the research work of image segmentation based on PCNN has been carried out for decades, but there are still many difficulties, mainly in the following aspects:

1) The segmentation result of the image was affected by the scene internal and external interference;

2) At present, there is no better method to realize the automation and optimization of PCNN parameter setting because of the complexity of PCNN parameter setting, so it brings great workload to researchers;

3) Different segmentation methods only aim at specific image types and have no universality;

4) There is no objective criterion for the success of segmentation, which has a certain impact on the evaluation of segmentation images and segmentation algorithms;

5) Due to the current understanding of mammalian animal visual system there are still some limitations, only in function simulation rather than in the structure are simulated, which leads to the theoretical model of PCNN can get the results through the human visual nervous system observed there is a big gap, the final effect is far less to the level of the human visual system.

2.2. Applications in medical image fusion

There is a growing interest and application of the imaging technologies in the areas of medical diagnostics, analysis and historical documentation. Medical image fusion is a method of integrating information from multiple image formats. Medical image fusion plays an important role in medical diagnostics and treatment. In recent years, medical image fusion methods at home and abroad have weighted average, local variance, multi resolution tower fusion algorithm and neural network method [11]. Among them, the wavelet multi-resolution fusion algorithm is most widely used, but this method has some weak points, such as computational complexity and poor real-time performance in a large number of medical image data processing. LIU Wenmin [12] proposed a new medical image fusion algorithm based on lifting wavelet transform, combined with the Pulse Coupled Neural Networks（PCNN）and pixel point of nonlinear filtering gravitation. A fusion rule based on the area average gray is adopted in low-frequency coefficients. Adaptive PCNN fusion rule is adopted in high-frequency coefficients.

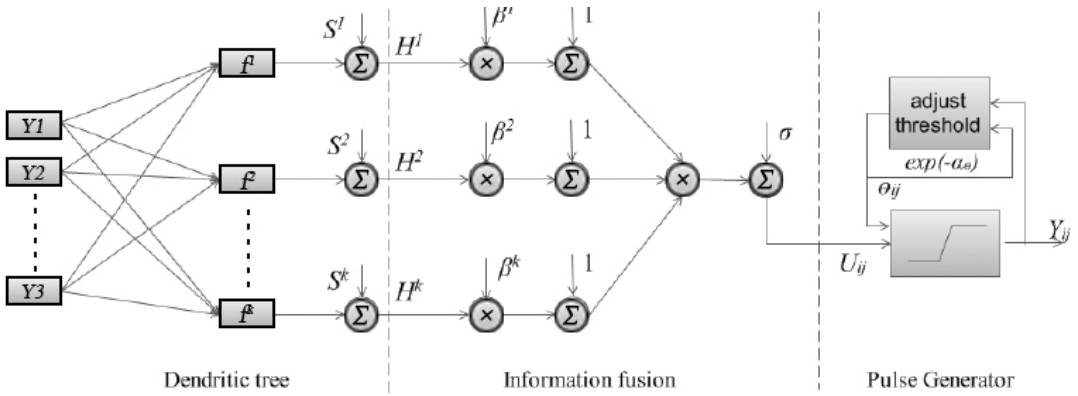

Fig.2. The neuron model of *m*-PCNN

Each type of medical image gives different information on a particular area of the body. PCNN has proved that is very suitable for image processing, especially image fusion [13-15]. Recently, several

methods of image fusion, such as shearlet-PCNN, NSCT-SF-PCNN, and NSCT-MSF-PCNN were proposed by researchers, which is used PCNN to select decomposition coefficients in multi-scale [16-18]. The most widely used model of image fusion is *m*-PCNN [19-21]. Image fusion based on *m*-PCNN is a pixel-level method. Comparing to the conventional PCNN neuron, each *m*-PCNN neuron has multiple external stimuli, and the number of external stimuli can be adjusted according to practical demands, equal to the number of source images. Fig.2.present the neuron model of *m*-PCNN.

The mathematical expressions of the m-PCNN model are described as follows: S^k (k=2, 3,…, K, K is the total number of external inputs) is the external stimulus, f^k is the feed function. The sum between S^k and f^k is the k^{th} channel input, denoted as H^k. k is the weighting factor of the k^{th} channel, and it ranges from 0 to 1. σ is the level factor to adjust the average level of internal activity. θ is the firing threshold. V_θ and θ α are scaling terms. $\otimes$ is the convolution operation. Data fusion occurs in the internal state of the neuron. When all neurons are fired, the fusion is complete.

$$H_{ij}^k[n] = (M^k \otimes Y[n-1])_{ij} + S_{ij}^k \tag{1}$$

$$U_{ij}[n] = \prod_{k=2}^{K} (1 + \beta^k H_{ij}^k[n]) + \sigma \tag{2}$$

$$Y_{ij}[n] = \begin{cases} 1 & U_{ij}[n] > \theta_{ij}[n-1] \\ 0 & U_{ij}[n] \le \theta_{ij}[n-1] \end{cases} \tag{3}$$

$$\theta_{ij}[n] = \exp(-\alpha_\theta)\theta_{ij}[n-1] + V_\theta Y_{ij}[n-1] \tag{4}$$

3. Discussions

Although PCNN offers generality in terms of having the ability to apply the concept of training [22], the robustness of ANN methods is limited by the quality of the training data and the accuracy of convergence of the training algorithm. In order to improve the quality of the features and thereby to improve the robustness of the ANN, hybrids of neural networks and sequential processing with other fusion techniques can be employed. Some of examples of these are wavelet-neural network [23-25].

Overall, PCNNs have several benefits to image processing and are worth exploring though an understanding of their limitations is necessary. Also, for PCNNs to gain popularity and find usefulness, a better approach t setting parameters is necessary, and a better understanding the parameter relationships should be researched.

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