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Image Feature Extraction and Retrieval of the Euler Number to Chinese Herbal Medicine based on PCNN

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Abstract. In order to extract microscopic image feature information of traditional Chinese medicine effectively and simply and improve the precision of image retrieval, an image Euler number feature extraction and retrieval algorithm based on pulse coupled neural network (PCNN) was proposed. First of all, the PCNN model is introduced from the perspective of biological tissue image processing. Secondly, the CHM image is segmented into a series of binary correlation images using simplified PCNN. The Euler number of the edge information of each binary image in the generated binary image sequence is calculated, and a one-dimensional feature vector is constructed. Finally, the Euclidean distance is used to measure the similarity of the feature vector in the retrieval of CHM microscopic images. Euler number feature extraction and retrieval method is characterized by simple calculation and small amount of data. Compared with other methods, this algorithm has stronger robustness and retrieval accuracy, and certain feasibility.

1. Introduction

Image retrieval is an important research field in image processing and computer vision. How to retrieve images needed by users quickly and efficiently from large-scale image databases has become a very important and challenging research topic in the field of scientific research and commercial research. Content-based image retrieval (CBIR) technology is proposed to solve the problem of how to effectively retrieve relevant images from a large number of images. CBIR method can quantify the image features well and carry out effective contrast and matching greatly improve the retrieval accuracy [1]. CBIR builds an index by extracting the underlying visual features of the image as the characteristic values of the image, and then finds and sorts similar images by matching the characteristic values.

Chinese Herbal Medicine (CHM) is a traditional national industry in China. Modernization of traditional Chinese medicine is an important way to promote the development of Chinese medicine industry. Various changes in the domestic and international medical market and the development trend of the medical market in the 21st century have also brought various golden opportunities and severe challenges to Traditional Chinese Medicine. The identification, identification and retrieval of Traditional Chinese Medicine are particularly important because the quality and clinical efficacy of
Traditional Chinese Medicine are seriously affected by counterfeiting, inferiority and degradation. Traditional CHM recognition relies on subjective experience. The difference between chemical and physical CHM is mainly based on some instruments [2]. The use of information technology to search and identify CHM is a new development trend [3-4]. Modern recognition and retrieval of CHM based on image signal processing is one of the advanced methods of information technology. Although these methods have achieved some results, some methods need to introduce artificial feedback mechanism, the other need to train the classifier for many times. This has a certain effect on effective automatic real-time retrieval.

Therefore, a new method for extracting and retrieving microscopic image features of CHM based on PCNN and Euler number is presented. The original microscopic image is input into the PCNN model to generate a binary image sequence, and the Euler number of each image in the sequence is calculated, and a one-dimensional feature vector is constructed as the texture feature of the image. Finally, a set of microscopic image retrieval system of CHM is established by using Euclidean distance to match the characteristic values.

2. PCNN Model and Its Improvement

2.1. Traditional PCNN Model

PCNN is known as the third generation of artificial neural network, with the same structure of neurons. PCNN has been widely used in image segmentation, image denoises, and feature extraction, etc [5-7]. Each PCNN neuron is composed of the receiving part, the modulation part and the pulse generator part, which can be described by the following discrete equation

\[
F_y[n] = e^{-\alpha_y} F_y[n-1] + V_r \sum_{i} M_{ai} Y_i[n-1] + I_y
\]

\[
L_y[n] = e^{-\gamma_y} L_y[n-1] + V_i \sum_{i} W_{ai} Y_i[n-1]
\]

\[
U_{ij}[n] = F_y[n] (1 + \beta L_y[n])
\]

\[
\theta_{ij} = e^{-\alpha_{ij}} \theta_{ij}[n-1] + V_{\theta} Y_{ij}[n]
\]

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

Where \(ij\) is the label of neuron, \(I_y, F_y, L_y, U_{ij}, \theta_{ij}\) are the external stimulation of neuron, feedback input, linking input and internal activity, dynamic threshold respectively. \(M\) and \(W\) are linking weight matrices, \(V_r\) and \(V_{\theta}\) are amplitude constant, \(n\) is a cyclic iterative time, \(\alpha_y, \alpha_i, \alpha_{ij}\) and \(\alpha_{\theta}\) are time decay constants, \(\beta\) is linking strength, \(Y_{ij}\) is binary value output.

2.2. The Improved PCNN Model

The traditional PCNN model has some flaws in different image processing. To overcome some disadvantages such as multiple artificial set parameters, adaptation of poor performance and the repeated decline of exponential function, The traditional PCNN model is simplified and improved on the basis of literature [8], which can be described by the following discrete equation.

\[
F_y[n] = I_y
\]

\[
L_y[n] = \begin{cases} 1, & \sum_{a,b} Y_{ab}[n] > 0 \\ 0, & \text{otherwise} \end{cases}
\]
is a constant of threshold amplitude, which is adaptively selected for image pixel maximum $I_{\text{max}}$, $	heta_i$ is a larger constant. Internal activities $U_{ij}$ and binary output $Y_{ij}$ with the same type (3) and (5).

2.3. Binary sequence decomposition of PCNN images

When the image is processed using PCNN, the two-dimensional PCNN network corresponds to the $M \times N$ pixels of the two-dimensional input image. When the inner activity of neurons is greater than the discharge threshold, the adjacent neurons are stimulated through the smooth inhibitory relationship with the activated neurons connected with the adjacent neurons. If the internal activity of an adjacent neuron is greater than the excitation threshold, its output is one. The discharge time of similar neurons is recorded in the time matrix, which can reflect the spatio-temporal information relationship of the processed image. Thereby, the collective activation of similar neurons in the processing region can be effectively triggered, and the state information of the edge neurons is automatically protected by the adjustment of the smoothing suppression factor and the adaptive connection strength, and image processing such as filtering noise is realized.

There are many methods to generate binary image sequences [9-10]. For example, there are two methods such as equal interval quantization of gray level and binary processing of bit plane. However, the first method does not take into account the difference between adjacent pixels and different images correlation, while the second method only retains the high order plane after image decomposition information, discarded the low level information, resulting in the loss of image information. Neurons are processed in each iteration, the synchronization pulse emission characteristics of a specific neuron are used to activate the phase in its neighbourhood similar neurons when PCNN generates binary image sequence. The generated neuron clusters correspond to the similarity in the image local target region. Then it is composed of all the different small target areas for this iteration. A representation of the original image generated by a binary segmentation image with different iterations. The binary images of features are also different, and then all binary images are generated and the binary sequence image formed after several iterations.

3. Image feature extraction

After processing the PCNN model into a two-dimensional grayscale image, a series of pulsed output images will be produced. Its output is 0 and 1 only, so the pulse image is a binary image. Obviously, these pulse images contain a large amount of feature information, but cannot be classified as features of the original image. To this end, these binary image sequences need to be transformed to reduce the amount of data, and the transformed data can be used as a feature of the original data. If PCNN sums up the two-dimensional binary images in each iteration, the one-dimensional time series signal $G[n]$ can be obtained

$$G[n] = \sum_{i=1}^{N} Y[n]$$

$Y[n]$ is the binary image of the NTH output of PCNN.

Time series signals exhibit periodic behavior, with each neuron triggering an excitation at a time in each cycle. This signal is invariant to the rotation, scale translation and distortion of the input target image. For the time series of the entire input image, the distance between the peaks is constant, and the peak grayscale can also be used to obtain the scale and angle information of the input image target. Through this conversion, multi-dimensional feature information is converted into one-dimensional features, which greatly reduces the amount of calculation and storage of data.
If the appropriate parameters are selected, this time series will appear periodically and is suitable as the input of statistical classifier or pattern classification neural network. The advantages of this transformation are obvious: simple calculation, little data, easy operation, etc., but there are also disadvantages, mainly reflected in the poor anti-interference ability. Time series greatly reduces the amount of data, but has poor anti-interference ability. Therefore, a time series feature based on Euler number is proposed as the image eigenvalue method.

In digital image processing, the image properties which do not change under the circumstances of translation, scaling and rotation are called topological properties of image. Euler number is a topological parameter that can describe the structure of an object, regardless of its specific geometry. The connectivity of the image and the number of holes in the region are topological properties, and their values remain unchanged after translation, rotation, stretch, compression and twist. For a given two-dimensional image, Euler number is defined as the difference between its connective body and the number of holes. Euler number is described as a regional topology descriptor, which describes regional connectivity.

Its global definition formula is

\[ E = C - H \]  

Where, \( C \) is the number of connected bodies in the image, and \( H \) is the number of holes in the image. When calculating the connected volume and hole, the image connecting methods are divided into 4 connecting and 8 connecting ones. Different connecting methods will lead to different results.

Euler number of binary Chinese medicinal image can also be calculated by local properties. In the cell image of binary Chinese medicinal materials, Euler number can be calculated by using the nearest pixel value. The calculation formulas of 4-connected and 8-connected images are

\[ E(4) = (S_1 - S_3 + 2X) / 4 \]  
\[ E(8) = (S_1 - S_3 - 2X) / 4 \]  

the values of \( S_1, S_3 \) and \( X \) represent the number of the following patterns of all 2*2 squares in the binary image.

- \( S_1 \): numbers of permutations of one independent 1 and three consecutive 0.
- \( S_3 \): numbers of permutations of three consecutive 1 and one independent 0.
- \( X \): numbers of two 1 on one diagonal and two 0 on the other diagonal.

The microscopic images of Chinese medicinal materials are processed by equalization and gray-scale processing, and then input the pulse-coupled neural network model for iterative processing to decompose a sequence containing a certain number of binary Chinese medicinal materials microscopic images. Then, Euler number of each binary image in the 8-connected mode in the sequence of binary Chinese medicinal materials microscopic images is calculated through equation (12) to form a feature vector, which is used as the feature vector of Chinese medicinal materials microscopic images.

4. The experimental results and analysis

In this experiment, the improved PCNN model and Euler number topological features are used to extract and retrieve the microscopic images of CHM. Firstly, Euler number feature vector extraction based on PCNN model and anti-geometric distortion experiments are carried out. The microscopic images of radix aconiti and radix aucklandiae are randomly selected from the microscopic library of CHM in figure 1 and 2. In the feature vector graph, the abscissa is the number of iterations of the image, and the ordinate is the Euler value of the corresponding number of iterations.

(a) The original image  
(b) Euler number feature vector
Figure 1. The feature vector of radix aconiti image under geometric deformation.
From figure 1, figure 2 and table 1, it can be seen the experimental result that the CHM’s image feature vector of the Euler number using PCNN model have invariance under the geometric transformation of rotation and scale, and the difference between the feature vector of the different microscopic of CHM is quite different. As can be seen from table 1, the Euclidean distance error of the Euler number feature vector of the same image is small when the image is distorted by rotation, scaling, etc. In order to verify the feasibility of the proposed algorithm for the microscopic image retrieval of CHM, 10 kinds of microscopic images of CHM are randomly extracted as retrieval objects, and (a)-(j) codes are applied to them as the simulated image library.

(a) rhubarb    (b) codonopsis pilosula    (c) angelica    (d) licorice    (e) fleece-flower root

(f) coptis chinensis    (g) ginseng    (h) notoginseng    (i) ginger    (j) asarum

Figure 3. 10 kinds of microscopic images of rhizomes
It can be seen from figure 3 and figure 4 that that binary image sequence of the microscopic images of CHM in the image library can extract the Euler number feature vector when it is processed by the PCNN, and the feature vectors of each image are also different. By calculating the Euclidean distance difference between rhubarb and other microscopic image feature vectors in table 2, it can be seen that the distance difference between rhubarb and its own image is the smallest (zero), and the distance difference between rhubarb and other image feature vectors is large. Considering the slight influence of rotation, scaling and other distortions on the feature vectors in image retrieval, a different Euler number feature vector retrieval error (0.4 $\times 10^4$ in rhubarb) can be set in content-based retrieval for different images.
5. Conclusions
In this paper, an algorithm for extracting and retrieving microscopic image features of CHM based on PCNN is proposed. The Euler number feature obtained by processing the CHM microscopic image with PCNN model is to decompose the CHM microscopic image into binary image sequence, and extract the Euler number feature of the binary image sequence to apply to the retrieval of the original CHM microscopic image. Then, according to the similarity of characteristic quantity, the related images were searched, and finally the required CHM images were retrieved.

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