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Color Image Segmentation Based on PCNN

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Abstract. In view of the ignition characteristics of PCNN, when the traditional PCNN model is used in image segmentation, the final segmentation images are two valued images. Although the two value image has the advantages of easy identification and convenient storage, but for the following processing of image recognition, image compression and feature extraction, the singleness of two valued image can not meet the needs of people. Therefore, based on the previous work, the maximum Shannon entropy, maximum gray entropy and maximum variance ratio are used to improve the traditional PCNN. The final output of the model has three patterns: color, gray and two values, which is convenient for the subsequent processing of images. Experimental results show that the proposed algorithm can achieve the effective segmentation of color images, and the segmentation effect is significantly better than the traditional algorithm.

Keywords: PCNN; color image; image segmentation; maximum Shannon entropy; maximum entropy; maximum variance ratio

AMS Mathematics Subject Classification (2010): 62H35

1 Introduction

Image segmentation is to separate different regions of the image that satisfy some similarity criteria, such as gray level, texture or color. These different areas tend to have different significance. With the rapid development of computer science and technology, more and more attention has been paid to the use of computer in processing images. The Traditional color image segmentation focuses on two aspects: one is to choose the right color space; the other is to adopt the appropriate segmentation technology in two. In the actual operation process, operators often choose different color space and segmentation method according to different requirements. For example, in document [1], in order to divide the complete iris, the iris is transferred to the HSI space to reduce the correlation

of each component. In order to detect moving objects accurately; the document [2] transforms the image into HSV space to reduce the color difference between the object and the object around it; the document [3] uses the correlation of each component of RGB space to segment true color images, thus reducing the segmentation error. The algorithms for color image segmentation are also emerging in recent years, such as threshold method [4], ant colony algorithm [5], watershed algorithm [6] and so on.

In recent years, Pulse coupled neural network of cat visual cortex model based on Eckhorn [7-9] (Pulse Coupled Neural Net, PCNN) has been widely used to study the field of image processing, and shows its superiority, especially in the application of image segmentation, PCNN can effectively Overlap between the separation of the target and the background, It can also deal with the problem of small gray level change and spatial incoherence in the target. The existing algorithms based on PCNN are mostly applied to the segmentation of gray images, until a color image segmentation method based on PCNN is proposed. In [10], after the color image is grayed out, the maximum iteration number is determined by the maximum Shannon entropy, and the binary image output from the last iteration is used as the final segmentation image. Although the segmentation image obtained by this method has more information than other iterative output two valued images, its anti noise ability is poor and easy to produce over segmentation phenomenon. The literature [11] transforms the RGB image into the HSV space, uses PCNN to iterate each component graph, and uses the maximum Shannon entropy to determine the final iteration number of each component graph, finally, the binary images produced by each component are merged. Although this method provides a new idea for color image segmentation, the effect of merging segmentation graph is very poor, it can not retain the original image texture, and can not accurately express the edge of the original image, and its recognition rate is low. Document [12] uses PCNN model to iterate the three components of R, G and B of color images, then, four screening schemes are designed on the basis of the probability merging strategy, the small merger strategy, the maximum Shannon entropy and the minimum cross entropy. Although this method improves the accuracy of the output binary image, it can not change the nature of the output image as the binary image. In view of the above problems, the color image is divided into R, G and B components firstly. Then, the binary image of PCNN iteration is filtered by using the maximum Shannon entropy, and the selected binary images are superimposed, finally, gray level entropy is used to determine the maximum gray level of the superposition, and the gray image of the three components is merged to obtain the color segmentation diagram. Experimental results show that the segmentation method used in this paper can not only retain the binary image texture and edges, and can obtain brightness characteristics of gray image and color image color feature, which will follow-up processing of image compression and recognition to improve the accuracy of

great help.

2. PCNN basic model

Eckhorn model is not suitable for image processing because of its many limitations, and many scholars have made a lot of improvements related to it. PCNN model is evolved from the Eckhorn model. Compared with Eckhorn model, it is more suitable for image processing applications, its mathematical model is

$$F_{ij}(n) = e^{-\alpha_F \Delta_t} F_{ij}(n-1) + S_{ij} + V_F \sum_{k,l} M_{ij,kl} Y_{kl} Y_{kl}(n-1)$$

$$L_{ij}(n) = e^{-\alpha_L \Delta_t} L_{ij}(n-1) + V_L \sum_{k,l} M_{ij,kl} Y_{kl}(n-1)$$

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

$$\theta_{ij}(n) = e^{-\alpha_\theta \Delta_t} \theta_{ij}(n-1) + V_\theta Y_{ij}(n-1)$$

$$Y_{ij}(n) = step(U_{ij}(n) - \theta_{ij}(n))$$

In the formula, subscript ij is the label of neurons, and S_{ij}, F_{ij}, L_{ij}, U_{ij}, θ_{ij} are external stimuli, feed inputs, link inputs, internal activations (i.e., pre synaptic potentials) and dynamic thresholds of neuronal ij, M is a connection weight matrix, V_F, V_L and V_θ are amplitude constants, β is the link factor, α_θ α_F, α_L are the corresponding attenuation coefficients, Δ_t is the time constant, n is the number of iterations, Y_{ij} is output.

3. PCNN model segmentation principle

To segment the image by PCNN, each pixel of the $M \times N$ image to be segmented corresponds to the neuron of a two-dimensional neural network. The gray value of each pixel is the external stimulus of the corresponding neuron. At the same time, the initial value of the neuron (initial value is 1) and the corresponding threshold θ_{ij} are initialized, when the first iteration starts, the external stimulus of each neuron is compared with the threshold, and if the external stimulus is greater than the threshold, the neuron will ignite, at the same time, the threshold of the neuron also increases instantaneously. As the iterative process proceeds slowly, there is a strong connectivity between neurons. In the subsequent iterations, if the gray value of the pixel corresponding to the firing neuron is similar to the gray value of the neighboring neurons, and the internal activation of the neighboring neurons is greater than the corresponding threshold, the neighboring neurons will acquire the ignition. That is to say, if the gray value of one region of the input image has a high similarity, the neurons corresponding to the pixel of the region will form a cluster. Once one of the neurons is ignited, the collective ignition will occur in this region.

Therefore, the image segmentation can be done by using the similarity of PCNN ignition capture and cluster characteristics.

4. PCNN model segmentation

4.1. Maximum Shannon entropy criterion

For binary images, the Shannon entropy [13] can well reflect the amount of information contained in it. The bigger the Shannon entropy of the binary image generated by the PCNN model is, the better the effect of the iterative segmentation is, and the larger the information content of the original image is. Therefore, the Shannon entropy maximum binary image will be regarded as the best segmentation result in the iterative process. The Shannon entropy is defined as

$$H(P) = -P_1 \ln P_1 - P_0 \ln P_0$$

In the formula, P_0 and P_1 are the probabilities of the pixel values of 0 and 1 in each of the binary images output at each iteration.

4.2. Maximum entropy criterion

The image gray entropy is a statistical characteristics of gray image, which describes the distribution of gray image information space, if the gray image gray entropy is bigger, the more uniform distribution of gray, which contains more information. For a maximum gray level for $M \times N$ gray image of L. The gray value of pixel number for i is n_i, the corresponding probability is P_i, then the following image gray entropy calculation of H :

$$H = -\sum_{i=1}^{L} P_i \times \log_2 P_i$$

Among them,

$$P_i = n_i / (M \times N)$$

4.3. Maximum variance ratio criterion

For a double peak gray image, its gray distribution presents a "U" shape, the gray value of the bottom of the "U" is set as a threshold, which can be used to separate the target and background of the image. For the image with gray level $S = (1,2,3,\cdots,i,\cdots,j)$, the gray level T of the image is used as the segmentation threshold, divide the image into two classes, C_1 and C_2 of $S_1 = (1,2,3,\cdots,T)$, $S_2 = (T+1, T+2,\cdots,L)$, The intra class variance σ_W^2 and the inter class variance σ_B^2 can be obtained by the lower form

$$\sigma_W^2 = \omega_1 \sigma_1^2 + \omega_2 \sigma_2^2$$

$$= \frac{1}{N}\left[\sum_{i\in S_1}(i-\mu_1)^2 n_i + \sum_{i\in S_2}(i-\mu_2)^2 n_i\right]$$

$$\sigma_B^2 = \omega_1(\mu_1-\mu_T)^2 + \omega_2(\mu_2-\mu_T)^2$$

$$= \frac{1}{N}\left[\sum_{i\in S_1}(\mu_1-\mu_T)^2 n_i + \sum_{i\in S_2}(\mu_2-\mu_T)^2 n_i\right]$$

In the formula, N is the total number of pixels σ_1^2, σ_2^2 is the variance of C_1 and C_2, ω_1 and ω_2 are the probability of occurrence of C_1 and C_2, μ_1 and μ_2 are the average gray level of C_1 and C_2, and μ_T is the average gray value of the image. The maximum variance ratio is

$$\eta = \max\left[\frac{\sigma_B^2}{\sigma_W^2}\right]$$

The variance between classes reflects the difference between the two categories of the target and the background in the image, and the class variance represents the difference between the same pixels. When the maximum value of η is obtained, the variance between classes is the largest and the variance within class is the smallest, that is, the gray values between different pixels are very different, and the gray values between similar pixels are very small. Therefore, when the variance ratio [14] is the maximum, the threshold segmentation is the best.

4.4. Color selection

Choosing the appropriate color space, extracting the components of the color image, and then segmenting them one by one, which is a common method for color image segmentation. HSV and RGB color space is the most widely used space at present. Relative to the HSV space, the correlation of each component in the RGB color space is relatively large, and the use of the PCNN model for the three components segmentation will produce some constraints. Therefore, in the RGB space, each component of the color image is segmented, its fault tolerance is much larger than that in the HSV space, and it does not affect the final result of segmentation because of a few error points of a segmentation component. Therefore, in RGB color space, using PCNN segmentation, combined with a specific combination method, you can get a good segmentation effect.

4.5. Using model segmentation

4.5.1. Gray model

Based on the traditional PCNN model for segmentation, no matter what method is used to determine the final number of iterations, the obtained images are all binary images. Each pixel of binary image is black or white, there is no intermediate transition pixels, and can

only describe the outline of the object, the details of the object is often not well expressed. At this time, a higher gray level is needed to describe the details of the image. Therefore, in this paper, the maximum Shannon entropy is used to filter the binary images generated by iteration, and then the selected binary images are superimposed to obtain a gray level gray image.

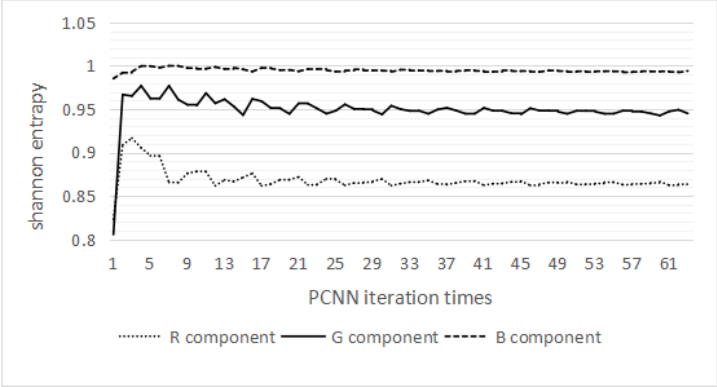

Figure 1:

It can be observed from the broken line graph of Figure 1 that the Shannon entropy of the binary image of R, G and B increases first and then decreases with the iteration of the algorithm, when the iteration is more than 45 times, the Shannon entropy change tends to be stable. Therefore, when the algorithm is iterated to a certain number of times, the output entropy of Shannon is not very different. In order not to make the algorithm to prepare sufficient candidate graphs by infinite iteration, the Shannon entropy $H(P)$ of forty-fifth iterations of R, G and B is taken as the threshold value, and the images before the forty-fifth iteration are screened out. When the Shannon entropy is greater than or equal to a, the corresponding two value image and retained as candidate grayscale overlay, otherwise it is rejected. For binary image after forty-fifth times, because of the difference of Shannon entropy is not big, all of them are used as candidate map of gray superposition

In order to obtain grayscale L gray image, the candidate must be in the binary image selected $L-1$ images are superposed. Accordingly, for R, G, B of each component, PCNN requires at least $L-1$ iterative times, which makes the algorithm running time is too long. On the contrary, if the algorithm does not iterative enough times to provide enough binary image screening, will make the gray image overlay is not bright enough, only the Shannon entropy of low binary image is superimposed, resulting in the loss of information overlay to solve the above problem, this method of human intervention, the provisions of the superimposed image the gray level between $L_{\min} \sim L_{\max}$ ($L_{\min}$ is the minimum gray level, $L_{\max}$ is the maximum gray level). Gray level superposition graph

will increase with the two value image overlay, when it exceeds $L_{\min}$, the algorithm starts recording every superimposed image output gray The degree of entropy, gray level until the gray level reached $L_{\max}$. Gray entropy corresponds to the maximum as the maximum gray level of the image. A lot of information superimposed so that it can ensure the superimposed image component map after segmentation can not only retain the original, but also because too many times to avoid the iterative algorithm, the algorithm consumes a long time. In this paper the $L_{\min}$ value is set to 120, $L_{\max}$ will be set to 160.

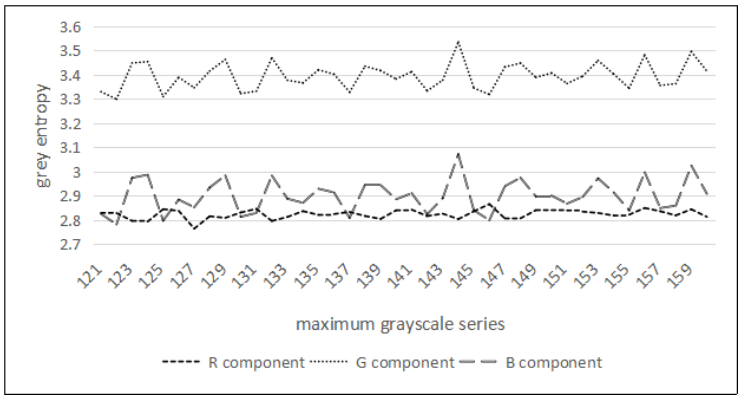

Figure 2:

From Figure 2, we can see that the gray entropy of G component and B component is the largest when 143 binary images are superimposed, and the gray entropy is the largest when the R component is superimposed to 145. Therefore, 144 is taken as the maximum gray level of the G and B component segmentation overlay graph, and 146 is taken as the maximum gray level of the R component segmentation superposition graph of two

R component superposition diagram G component superposition diagram B component superposition diagram

Figure 3:

Table 1: Iteration number statistics

	R component	G component	B component
Algorithm in this paper	183	186	189

For stacked Cato, the greater the pixel values of pixels are superimposed times are more and more, in each iterative process, the ignition frequency of the pixel is increased. In other words, In other words, the probability of the pixel as the target point is also greater .In fact, In fact, the superposition process of PCNN binary image is the superposition process of the target area, that is the accumulation process of the target information quantity.

4.5.2. Color mode

Compared with the binary output diagram, the grayscale image can clearly express the depth of different colors, and can accurately describe the different colors on different brightness. However, in the subsequent processing of image recognition and feature extraction, the color features of objects also play an important role. Therefore, it is not enough to obtain only the gray scale after segmentation. In this paper, the grayscale images of different components are merged, so that the segmentation graph with color features is obtained

Figure 4: Color merge diagram

4.5.3. The binary model

We know that, compared with image storage, in the same length, two element features are often much smaller than floating point features, and simple two valued description can solve large-scale real-time visual problems. Therefore, although gray and color images have advantages in information description and color expression, the effect of binary image is not worse than that of gray image and color image under certain circumstances. To this end, this paper redesigned a method to obtain more high-quality binary images

The rgb2gay function in MATLAB is used to gray the input Lena image, and the gray Lena image is iterated by PCNN. Before the iteration number of the algorithm is not more than 45 times, it is known from the statistics of Shannon entropy in Figure 1 that the quality of the binary images produced by the algorithm is different. To this end, referring to the method of obtaining the gray superposition map, the Shannon entropy of the two value image of the forty-fifth iteration is used as the threshold to filter the binary images of the first 45 iterations, then the selected binary images are superimposed, and finally 30 images are selected from the 45 images for stacking.

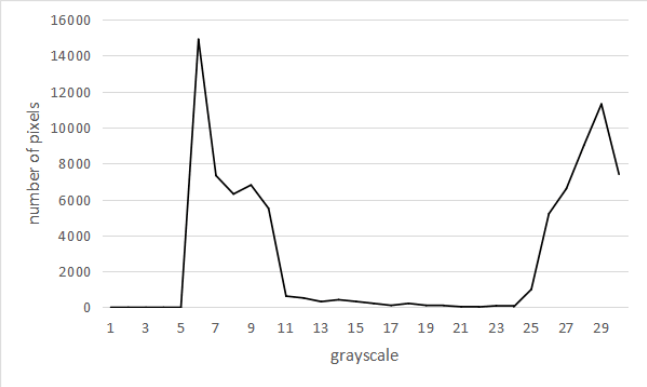

Figure 5:

According to the principle of PCNN segmentation, the smaller pixels, the backlight of the hair and the cap, and the background often don't happen the ignition, but the threshold of neurons in these regions decreases with the attenuation coefficient, when its value is less than the set value A, the background point and the small gray level will occur collective ignition phenomenon, after that, the threshold of the corresponding neurons will increase dramatically, which is the oscillation of PCNN segmentation. Because of the presence of PCNN oscillations, The background points are fired once every certain iteration. By superimposing the output binary image, the gray level of the target and the background are concentrated in a pixel segment, so that the gray distribution of the superimposed image appears "U" font, as shown in Figure 5.

In order to obtain binary image with relatively good quality, In this paper, we use the oscillation of PCNN segmentation and the maximum variance ratio to select the appropriate threshold to segment the superimposed image. That is, when the gray value of the pixel is greater than A, the size is set to 1, otherwise the size will be set to 0.According to the maximum variance ratio criterion, the threshold B of the superposition graph is obtained.

Algorithm in this paper Document [10] algorithm Document [13] algorithm

Figure 6: Comparison of two value output diagrams

5. Experimental results and simulation

The simulation experiment is carried out by MATLAB. The resolution of RGB image is

256 x 256., the experimental parameters are $\alpha_F = 0.1$, $\alpha_L = 2$, $\alpha_E = 1$, $\beta = 0.4$, $V_F = 0.5$ $V_L = 0.2$, $V_\theta = 0.3$, the connection weight matrix is [-0.03 -0.03 -0.03, -0.03 0 -0.03; -0.03 -0.03 -0.03].

Table 2: Statistics of the number of iterations of each component of the experimental image

	R component	G component	B component	Document [10]	Document [13]	This paper
road diagram	172	165	163	9	10	45
lotus diagram	143	159	153	13	17	45

Original R G B color merge

Original R G B color merge

Figure 7: Comparison of superposition and merging graphs

Algorithm in this paper Maximum Shannon entropy Maximum gray entropy

Algorithm in this paper Maximum Shannon entropy Maximum gray entropy

Figure 8: Comparison of two value output diagrams

In order to verify the feasibility of the algorithm, the road and lotus pictures are tested, and the results of the experiment are shown in Figure 7. The number of iterations of the R component of the road image is more than that of the iterative method, so the segmentation graph is relatively brighter. The green information of the road map is less, and the number of B component superposition is less, leading to the superposition of the whole picture is dark, especially the forest part is unrecognizable. For the original picture of lotus, its red information is more abundant, therefore, in the superposition of R components, although the maximum gray level is not particularly large, the lotus fraction is completely segmented. Finally, the binary segmentation algorithm designed in this paper is compared with document [10] and document [13]. The images in document [10] and document [13] are richer in details, but at the same time they contain a large amount of background information and noise. On the contrary, the binary of the output of this method in this paper can preserve most of the original target information and is less affected by noise, so it is a more effective segmentation method.

In order to further verify the effectiveness of the algorithm, the error misclassification rate is used to quantitatively evaluate the proposed algorithm and the literature [10] and [13], as shown in table 4.

The error misclassification rate is the percentage of all pixels in the entire ideal image that are erroneously segmented. The expression is

$$r = \frac{1}{2} \frac{\sum_{q=1}^{c} | m_q - n_q |}{\sum_{q=1}^{c} | n_q |}$$

In the formula, m_q is the number of pixels in the region marked as q in the segmentation result, and $q = 1,2,\cdots,c$ is the number of pixels in the ideal segmentation image which belongs to the label q region, $q = 1,2,\cdots,c$.

It can be seen from table 4 that the error misclassification rate of the proposed algorithm is lower than that of references [10] and [13], which further demonstrates the effectiveness of the proposed algorithm.

	algorithm in this paper	Document [10]	Document [13]
road diagram	0.1254	0.2153	0.1436
lotus diagram	0.1124	0.1967	0.1876

Table 4: Error rate comparison

6. Conclusion

On the basis of PCNN, the maximum Shannon entropy and the maximum gray entropy are used to segment the image, gray images and color images with large amount of information are obtained. This is of great help to the subsequent processing of segmentation (e.g. image recognition, image compression, feature extraction, etc.).In addition, a new binary image segmentation method is proposed by using the maximum Shannon entropy and the maximum variance ratio. A large number of experiments show that the segmentation method proposed in this paper can not only preserve the texture and edge information of binary images, moreover, the brightness feature of gray image and the color feature of color image can be obtained. This will greatly improve the accuracy of image compression, recognition and other follow-up processing. At the same time, this algorithm is the first attempt to select and stack the binary image of the traditional PCNN algorithm to get three better segmentation patterns. Therefore, there are also some problems. Because the segmentation graph of the three models is obtained by a large number of iterations, the designed algorithm gets better results, but the running time is relatively long. Therefore, how to optimize the model and make the algorithm more efficient is the focus of the future research.

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