结合模糊聚类与支持向量机的图像分割

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摘 要:提出一种新的混合的图像分割方法,利用模糊C均值聚类与支持向量机两种方法相结合。此方法首先将图像的空间分布信息作为支持向量机的特征分量,再用模糊C均值聚类获得的分类结果作为支持向量机所需的初始训练样本,并对图像的所有像素点进行分类,同一类中的像素点形成一个分割区域,以此获得图像分割。实验表明,此将模糊C均值与支持向量机结合的新方法获得的图像分割效果较好,在一定程度上解决了支持向量机特征维数过大所导致的维数灾难问题。

关键词:模糊聚类;支持向量机;图像分割;空间分布

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Image Segmentation Combined FCM and SVM

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Abstract: Propose a new hybrid methods for image segmentation combined Support Vector Machine (SVM) with C mean fuzzy clustering. This method takes the spatial distributed information as component characteristics of the SVM, and the classification results from fuzzy clustering as the initial training samples of the SVM. Then the pixels of the image are classified by SVM and the pixels in the same class form a segmental region to obtain image segmentation. The experimental results show that the new methods combing fuzzy clustering and SVM can get better results and to a certain extent solve the dimension disaster problem caused by large dimension of SVM.

Key words: fuzzy clustering; support vector machines; image segmentation; spatial distribution

0 Introduction

Image segmentation[1] is just to divide an image into different sub-images with different characters and extract some interested objects. It is the most essential and important content of research on low-level computer vision, and is a key technique for image analysis, understanding and description because the quality of segmentation results affects the quality of succeeding analysis, recognition and explaining. Image segmentation is applied in a lot of fields such as computer vision, image coding, pattern recognition, medical image and so on[2].

Images themselves are very uncertain and inaccurate. It is found that fuzzy theory is able to give a good description of such uncertainties and image segmentation is just the classification of image pixels[3]. In recent years, some experts are making efforts to apply the fuzzy clustering method in image segmentation, and it is more effective than the traditional image processing method[4]. Recently statistical learning theory has received considerable attention proposed based on small sample data, which is all important and development of traditional statistics. Support Vector Machines (SVM)[5-8] algorithms based on the foundations of statistical learning theory show excellent learning performance, which have been successfully extended from basic classification tasks to regression, density estimation, novelty detection, etc.

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Unlike traditional methods, which minimize the empirical training error, SVM makes use of the structure risk minimization principle, which may bring on a good generalization performance.

In recent years, with the new theories and new methods appear constantly, the mix of features combination and a variety of segmentation method is widely used in image segmentation[9-11], and got good effect. And about how to select the effective image spatial distribution characteristics to classify and the problem how to classify general nonlinear gray distribution of image research less. In this paper proposed an algorithm combines the spatial clustering and the Support Vector Machine (SVM) theory, in order to get better image segmentation effect.

1 Two-dimensional vector representation of image gray and the spatial information of image and the definition of two-dimensional histogram

The size of image is $M\times N$, gray scale ranges from 0 to $L-1$. If use Z for L grey value, $Z=\{z_0 | z_0 \in [0, L-1]\}$. Clearly, gray value $f(m,n)$ of the image coordinates (m,n) is a value of collection $f(m,n) \in Z$. Define the neighborhood average gray level $g(m,n)$ of coordinates (m,n):

$$g(m,n) = \frac{1}{s\times s}\sum_{i=-(s-1)2}^{(s-1)/2}\sum_{j=-(s-1)/2}^{(s-1)/2} f(m+i,n+j) \tag{1}$$

Here s is the width of the square neighborhood window $f(m,n)$, typically taking an odd number, this article takes 3. Symmetrical continuation for edge cases.

For $g(m,n)$, the following formula is set up

$$g(m,n) = \frac{1}{s\times s}\sum_{i=-(s-1)2}^{(s-1)/2}\sum_{j=-(s-1)/2}^{(s-1)/2} f(m+i,n+j) < \frac{1}{s\times s}\sum_{i=-(s-1)2}^{(s-1)/2}\sum_{j=-(s-1)/2}^{(s-1)/2} L = L \tag{2}$$

And due to $f(m,n)\geqslant 0$, combined with formula (2), so there are $0\leqslant g(m,n)<L$, neighborhood average gray level $g(m,n)$ and image (m,n) has the same gray level range, $g(m,n)\in Z$.

For any frame $f(m,n)$, can use matrix representation

$$[F(m,n)]_{(M\times N)\times 2} = [f(m,n), g(m,n)] = \begin{bmatrix} f(0,0) & g(0,0) \\ M & M \\ f(0,N-1) & g(0,N-1) \\ f(1,0) & g(1,0) \\ M & M \\ f(1,N-1) & g(1,N-1) \\ M & M \\ f(M-1,0) & g(M-1,0) \\ M & M \\ f(M-1,N-1) & g(M-1,N-1) \end{bmatrix} \tag{3}$$

For a $M\times N$ image $f(m,n)$, when use the vector representation $[f(m,n), g(m,n)]$, define and calculate its two-dimensional histogram. The 2-d histogram is defined in a $L\times L$ square area, abscissa is grey value of image pixel, ordinate is neighborhood average gray level of image pixel. Defined any point in histogram h_{ij}. It says probability of vector (i,j), (i,j) means $[f(m,n), g(m,n)]$, $0\leqslant i,j< L$. Use n_{ij} to express the frequency of vector (i,j) happening, then probability of vector (i,j)

$$h_{ij} = \frac{n_{ij}}{M\times N} \tag{4}$$

among them $0\leqslant i,j<L$, and

$$\sum_{i=0}^{L-1}\sum_{j=0}^{L-1} h_{ij} = 1 \tag{5}$$

2 FCM algorithm for image segmentation based on gray and spatial information

The traditional FCM algorithm for image segmentation using only the gray-level information, without considering the pixel space information and segmentation model is incomplete, lead to the traditional FCM algorithm applies only to segment low noise levels image, make two-dimensional vector composed of gray scale and neighborhood average gray level as characteristic vector of fuzzy clustering image segmentation, make row vector of formula (3) as the sample points of clustering, got FCM image segmentation algorithm based on gray level and the neighborhood information (marked SFCM). Select Euclid distance as distance norm. Specific algorithm steps are as follows:

Step 1: Got the image grayscale and neighborhood information of two-dimensional vector, $n=M\times N$. Give clustering category numbers $c(2\leqslant c\leqslant n)$ and $m(m>1)$. Set the iteration stop threshold $\varepsilon>0$. Initialize the clustering prototype model $V^{(0)}$, set the iteration counter $b=0$.

Step 2: Calculate or update dividing matrix:

For $\forall\ i,k$, if $\exists\, d_{ik}^{(b)} > 0$, there are

$$u_{ik}^{(b)} = \left\{ \sum_{j=1}^{c} \left[\frac{d_{ik}^{(b)}}{d_{jk}^{(b)}} \right]^{\frac{2}{m-i}} \right\}^{-1} \quad (6)$$

If $\exists\, i,r$, make $d_{ik}^{(b)} = 0$, then $u_{ir}^{(b)} = 1$, and when $j \neq i$, $u_{ir}^{(b)} = 1$.

Step 3: Update the clustering prototype model $V^{(b+1)}$:

$$v_i^{(b+1)} = \frac{\sum_{k=1}^{n} (u_{ik}^{(b)})^m \times x_k}{\sum_{k=1}^{n} (u_{ik}^{(b)})^m} \quad (7)$$

Step 4: if $\| V^{(b+1)} - V^{(b)} \| < \varepsilon$, to the next step, or set $b=b+1$, turn to the second step.

Step 5: Using maximum membership function method to fuzzy, use C_k to express category of number k sample points, then

$$C_k = \arg_i \{ \max(u_{ik}) \} \quad \forall\, i, \forall\, k \quad (8)$$

3 Use SVM to complete the image segmentation

(1) After using FCM to image, preliminarily got k areas($k=1,2,3\cdots$), mark the sample points belong to the area r as r, set $y_r = r$ as element of the output fields $Y = \{y_n\}$, use formula (9) to get spatial characteristics of component of each pixel $d_{is} = \{d_{1i}^s, d_{2i}^s, \cdots, d_{ki}^s\}$.

$$d_{rs}^s = 1 - \frac{\sum_{t \in \eta_s} u_{rt}\beta_t}{\sum_{c=1}^{c} \sum_{t \in \eta_s} u_{ct}\beta_t} \quad (9)$$

(2) Select n samples points randomly in the image as the input space, each samples points' s characteristics vector $x_i = \{x, d_{1i}^s, d_{2i}^s, \cdots, d_{ki}^s\}$, x is the pixel values of sample points, d_{ri}^s is spatial neighborhood information of pixel i. The output fields $Y=\{1,-1\}$ (two types of problems); or $Y=\{1,2,\cdots,k\}$ (many kind of problems), then the training set $S=\{(x_1,1),(x_2,2),\cdots,(x_k,k)\}$.

(3) Through the training set to get class of the associated I, a weight vector and a bias, (w_i, b_i), $i \in (1,2,\cdots,m)$, get decision function:

$$c(x) = \arg\ \max(<\omega_i \bullet x> + b_i) \quad 1 \leqslant i \leqslant k \quad (10)$$

(4) Take the feature vectors into (10), get the classification of each feature $y_r = c(x_i)$, put the feature vector of the same output into the same class.

(5) Get the feature vector of the new classification to iterate as the training sample return to step 2.

(6) Take the first component of the support vector sample points as the class of each pixel gray value, complete the image segmentation.

4 The experimental results and analysis

In order to verify the validity of the SFCM algorithm, use cameraman image to conduct segmentation experiment. Table 1 shows the quantitative description of the image segmentation result from two algorithms, among them Weight is the weight of space information, error count is the number of pixel classification error, Vpc is partition coefficient, Vpe is partition entropy. Also can see from the Table 1, the error pixel number of FCM algorithm is 1 476, the error pixel number of SFCM algorithm is 118, it greatly improves the accuracy compared with the traditional FCM algorithm. From the standpoint of partition coefficient, FCM、SFCM increase in turn, illustrate clustering effect of SFCM is better than FCM. From the standpoint of partition entropy, FCM、SFCM reduce in turn, also illustrate clustering effect of SFCM is better than FCM. But from Table 2, can see that the running time of SFCM is a little longer than FCM.

Table 1 Segmentation precision of two algorithms on synthetic test image with Gaussian noise

	Weight	Error count	Vpc	Vpe
FCM	0	1 476	0.870 9	0.219 6
SFCM	1	118	0.891 6	0.196 9

Table 2 Running time of two algorithms

	algorithm	running time
cameraman	FCM	1.543 139
	SFCM	1.870 870

Figure 1(a) shows the standard test segmentation image cameraman, FCM and SFCM two algorithms to figure 1(a) of the segmentation results were shown in figure 1(b)、(c), number of categories chosen as 3, G_m is the largest number of iterations. Can be seen from the diagram, as SFCM algorithm considering the effect of neighborhood pixels, it has a certain ability to filter out noise, the region after segmentation compared with the corresponding area after using the FCM algorithm segmentation is more clean.

5 Conclusion

The proposed algorithm combines the gray-scale of image and the spatial distribution information of image , and regard it as the characteristic vectors of support vector machine. It overcomes the lack of clustering algorithm on a variety of characteristics through the method of integration of the two kinds of image features. It is an attempt of the image segmentation of integration of a variety of characteristics and methods. This article discusses the segmentation algorithm only for grayscale images. The characteristic referenced finite (an image contains color, grayscale, texture and other features). Extracted from the image to the appropriate segmentation features, as well as a combination of important features as support vector machine characteristic components for further research.

(a) original image　(b) FCM　(c) SFCM

Figure 1　Segmentation results on standard image (cameraman)

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