

An Image Segmentation Method Based on Asynchronous Multiscale Similarity Measure

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Abstract. Image segmentation as a basic operation in computer vision is widely used in object detection, feature extraction and so on. In order to improve the effects and speed of image segmentation, an asynchronous processing mechanism of image segmentation was proposed, which use the image gray histogram and spatial contiguity and can avoid multiple iteration of the traditional FCM. A multiscale similarity measure method is proposed combined with the nonlinear sensitivity of gray difference of human based on the tree structure data representation of irregular rough classification of image block, using to merge the image blocks to obtain the segmentation result. Experimental results show that the proposed algorithm outperform the FCM in terms of segmentation effect and computation speed.

Keywords: Image segmentation · FCM · Asynchronous processing
Data representation · Multiscale similarity measure

1 Introduction

Image segmentation is a basic operation of computer vision in order to divided natural image into non overlapping meaningful region [1]. The essence of the segmentation method is how to represent each part of the image in a simple way, which makes the segmentation more meaningful and easy. The segmentation algorithm is divided into two categories according to the discontinuity and similarity of the two attributes. Both two properties are derived from the gray level. In recent years, image segmentation has been applied in many fields of computer vision, including feature extraction, object recognition, image registration and so on [2].

Gray is the most basic information of the image, which combining with clustering analysis has become the most direct segmentation method [3]. But the image segmentation is not qualitative [4], different segmentation methods will produce different results, which makes people pay special attention on the fuzzy clustering method and the most typical method is fuzzy C clustering FCM, which belongs to the unsupervised image segmentation method, of which advantages do segmentation computer automatically without human intervention. But FCM also has its obvious defects, the segmentation on the use of gray information, which leads to poor image segmentation effect, furthermore, FCM need to constantly update the center point, and calculate the

points to the degree of deviation from the center point of the calculation is time-consuming.

In view of the shortcomings of FCM, many improved algorithms have been proposed. fuzzy kernel clustering image segmentation method is used by Chaira which show [5] better effect; Ma combined with mathematical morphology method for multi regional medical image segmentation [6]; Neutrosophy theory was Introduced into image segmentation by Cheng, which provides a new description method of uncertainty, meanwhile the image segmentation algorithm based on Neutrosophy has been defined [7], which can select the threshold automatically and effectively; in the page [8] the image of wisdom segmentation algorithm is expanded to color texture image. The the blurring effect brought by the average operator is overcome by application of a median operator; instead of Euclidean distance measure algorithm, can the to give the disadvantage of same proportion of multi-dimensional sample weight of color features was overcome by replacing Euclidean distance with Mahalanobis distance.

The spatial neighborhood constraint term to the objective function and increase the correlation between the pixels neighborhood was added in order to improve the MNCM_S clustering algorithm [9].

Compared to FCM, the above algorithm has been improved in image segmentation effect, but it is by changing the cluster similarity measure, which in addition to considering the gray information also joined the space constraints, the edge information, increasing the calculation while improving effect.

This paper proposes an asynchronous multiscale similarity measure, which through the histogram for coarse segmentation and the using of space location of the to separate sub image blocks which in the same gray level but not adjacent. Finally multi-scale comprehensive similarity measure method are used and considering the nonlinear effect on the image block difference to gray eye sensitivity with gray value changes are combined to get the final segmentation. It can solve the contradiction between the segmentation effect and calculation.

2 The Overall Structure of the Algorithm

In order to solve the problem that the efficiency of fuzzy clustering is low and the image segmentation effect of complex structure is not is not satisfactory, this paper proposes a new method of image segmentation based on asynchronous multi-scale similarity measure. The traditional image segmentation based on FCM achieve the best classification by iteratively updating the center. The similarity measure is especially important in the iterative process. classification effect is not ideal if only gray information used for clustering, but if the similarity is expressed by complex formula, the computation is very huge because of many iterative times.

In this paper, the main methods to solve the above problems proceed in two steps, the first step is to use simple grey level to divide image into several small classes. Then using tree data structure to represent irregular image blocks, according to the spatial relationship of the image block is further divided into the same gray adjacent; The second step is use comprehensive measurement way for small class merging. The principle of the algorithm is shown in Fig. 1.

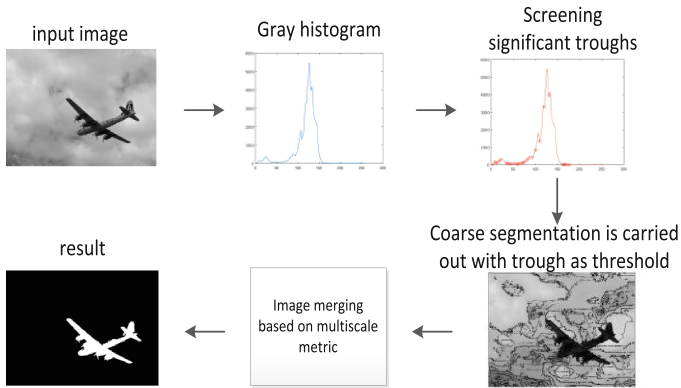


Fig. 1. Flow chart of the algorithm

3 C Mean Fuzzy Clustering Method [10]

Hard clustering [11] is a common method in cluster analysis, which aim to make the objective function minimum, by specifying the initial cluster center, according to the similarity criterion, the initial data is divided into classes and each iteration the center position. The commonly used objective function is shown in formula (1):

$$J_{HCM} = \sum_{i=1}^c \sum_{j=1}^{n_i} \|x_{ij} - v_i\|^2 \quad (1)$$

In the formula, n_i is the number of data in the i th class. v_i is the cluster center of i th class and x_{ij} is the j th data in the i th class. The center position is gotten by minimizing J_{HCM} by iterating and the iterative formula is:

$$v_i(t+1) = \frac{1}{n_i} \sum_{j=1}^{n_i} x_{ij}(t) \quad (2)$$

$v_i(t+1)$ is the new central position. When the location of the new central point changes very little compared with the previous time, the iteration is stopped and the threshold ε is chosen as the termination condition of the iteration.

$$\sum_{i=1}^c \|v_i(t+1) - v_i(t)\|^2 < \varepsilon \quad (3)$$

$v_i(t+1)$ and $v_i(t)$ are the i th center points of the $t+1$ and t rounds, respectively.

In order to express the uncertainty of the classification of objective things, people prefer to use fuzzy clustering for clustering analysis. Fuzzy clustering is used to describe the uncertainty of of real things through the subordination matrix.

$$J_{FCM} = \sum_{i=1}^c \sum_{j=1}^n \mu_{ij}^q \|x_j - v_i\|^2 \tag{4}$$

μ_{ij} is the degree of membership of data j in the class i , q is a constant, usually 2. The fuzzy clustering in the classification using the concept of membership to avoid the classification hard clustering process which in either this or that, clustering is a special case of fuzzy clustering, which μ_{ij} is only 0 or 1.

4 Asynchronous Multiscale Image Segmentation Algorithm

4.1 Image Segmentation Based on Gray Histogram

For a gray image, the gray histogram can describe the gray level distribution well, according to which can avoid the FCM iterative process, improving the efficiency of the calculation, the coarse classification of the histogram steps are as follows (Fig. 2):

- (1) Statistics the frequency $h(i)$ of each gray level of the image to be segmented, $i = 0, 1, 2, \dots, 255$.

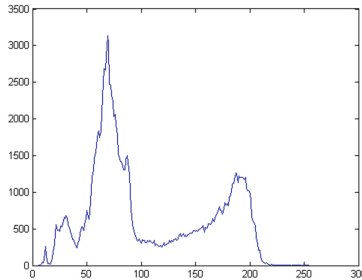


Fig. 2. Sketch map of gray histogram

- (2) find out all the peaks and troughs of the gray frequency.
For $i = 0, 1, 2, \dots, 255$, a set consisting satisfies the condition

$$\begin{cases} h(i) > h(i - 1) \\ h(i) > h(i + 1) \end{cases} \tag{5}$$

constitutes a crest vector P ,

$P = \{i | h(i) > h(i - 1) \ \& \ h(i) > h(i + 1), 0 < i < 255\}$. Similarly, For $i = 0, 1, 2, \dots, 255$ a set consisting satisfies the condition

$$\begin{cases} h(i) < h(i - 1) \\ h(i) < h(i + 1) \end{cases} \tag{6}$$

Consisting of a set of trough vectors.

$$V = \{i \mid h(i) < h(i-1) \ \& \ h(i) < h(i+1), 0 < i < 255\}$$

(3) screening the trough

In consideration of the pixel frequency of many pixels is only slightly fluctuating, it is necessary to further filter the trough in order to avoid excessive classification. It is obvious that the peaks and valleys appear alternately. If two pixels between the tops of too little, which satisfy the following equation:

$$\sum_{i=P(k-1)}^{P(k)} h(i) < \varepsilon \quad (7)$$

It can be considered that the two peaks have no clear boundaries, then remove the trough between the two peaks, and merge the two peaks in the following:

$$P'(k) = \frac{P(k+1) + P(k)}{2} \quad (8)$$

(4) further division of image segmentation according to the trough and spatial relations

According to the V (3), the image is segmented according to the gray value Regarding trough V as the threshold which get from (3) After the segmentation is completed, the adjacent blocks are divided into different classes according to the spatial relation. For a pixel (x, y) satisfy a point in the four neighborhood belongs to U , then $(x, y) \in U$, That is

$$U = \{(x, y) \mid (x-1, y-1) \in U \text{ or } (x+1, y-1) \in U \text{ or } (x-1, y+1) \in U \text{ or } (x+1, y+1) \in U\} \quad (9)$$

4.2 Multiscale Similarity Measure

Numerous information, such as gray, shape, contour and position can be extracted from the image by human, while the traditional segmentation method basically only little information, such as gray, edge and so on, which determines the traditional segmentation algorithm for complex image segmentation effect is not very good. In this paper, we use multiscale similarity measure to improve the image segmentation effect as much as possible.

(1) Gray measure

The gray level of the image is the most basic feature of the image, and the gray similarity measure is the most direct method to measure the similarity. In this paper, the gray similarity measure is expressed as formula (10) by calculating the gray difference between adjacent pixels of the adjacent image blocks:

$$Sg = \frac{N \times 255}{\sum_{x_i \in U} \sum_{x_j \in M_i} \|x_i - x_j\|} \quad (10)$$

In the formula(10), U is a set of adjacent pixel of sub image A and B . M_i is a set of adjacent pixel of x_i in B . N equals $\sum_{x_i \in U} M_i$.

(2) Information entropy measure

The information entropy is the amount of the information source of Shannon, which can represent the degree of chaos and the probability distribution vector. Suppose that the probability distribution vector of v is $(x_1 | p_1, x_2 | p_2, \dots, x_n | p_n)$. Then the information entropy of v can be expressed as:

$$E(v) = - \sum_{i=1}^n p_i \log_2(p_i) \tag{11}$$

For an image block or an image, its probability distribution can be expressed by gray level histogram. That is, $(x_1 | p_1, x_2 | p_2, \dots, x_n | p_n)$ n is the gray level, x_i is the gray value of the level i , $p_i = h(x_i)/N$, N is the number of pixels. The information entropy of the image can be expressed as:

$$E(v) = - \sum_{i=1}^n \log_2\left(\frac{h(x_i)}{N}\right) \tag{12}$$

The information entropy similarity measure Se of two images is expressed as:

$$Se = \frac{E(v_1) + E(v_2)}{E(v_1 \cup v_2)} \tag{13}$$

(3) Space adjacency measure

For two adjacent image blocks whose pixels are m and n , respectively, X_1, X_2 , if $m > n$, the spatial adjacency measure of the image is defined as:

$$Ss = \frac{1}{n} \left(\sum_{y_i \in X_2} flag(y_i) \right)^2 \tag{14}$$

When y is adjacent to X_1 , then $flag(y_i) = 1$, otherwise $flag(y_i) = 0$, the above three measures will be integrated:

$$S = \alpha Sg + \beta Se + \gamma Ss \tag{15}$$

The research shows that the nonlinear relationship between visual sensitivity to luminance difference [12]. In order to simulate visual effects, change the S in this way:

$$S' = 1 - \exp(-\lambda S) \tag{16}$$

5 Experiment and Analysis

In order to verify the effectiveness and efficiency of the algorithm, the four algorithms (plane, goose, horse, Eagle) were compared with the PCNN (Pulse coupled neural network) and PCM image segmentation methods.

The experimental images derive from the standard Berkeley image library, the fuzzy clustering center number $c = 2$, PCNN algorithm and $n = 16$, using Matlab 2012b, the computer is configured to Intel (R) Core (TM) i7-4790 CPU, 3.60 GHz 64 Win7 operating system. The segmentation results of each method are shown in Fig. 3 and the computation time of each algorithm is shown in Table 1. The experimental results show that the segmentation effect is good for the simple background and single tone, and the segmentation results are better than those of PCNN and FCM for complex objects with complex tone. In terms of algorithm time efficiency, the proposed algorithm has improved significantly relative to FCNN and FCM.

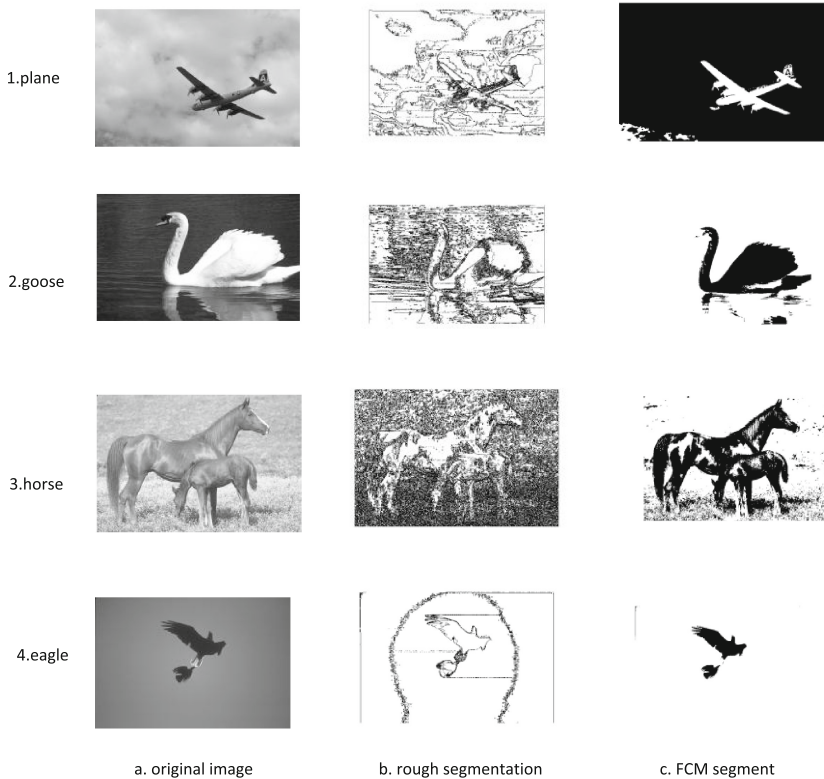


Fig. 3. (continued)

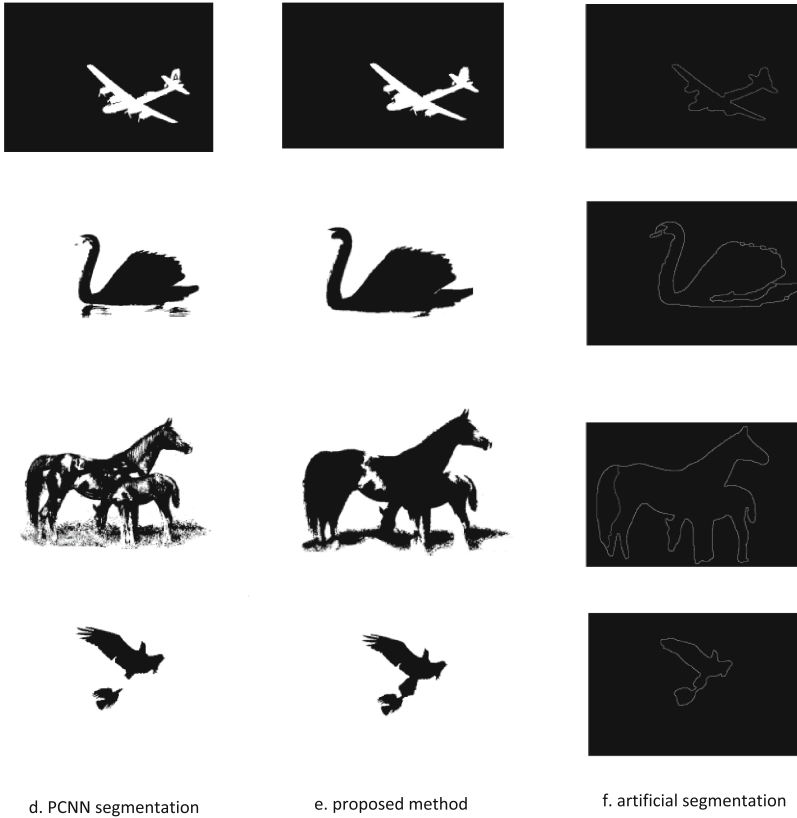


Fig. 3. Comparison of experimental results of segmentation

Table 1. Comparison of segmentation algorithm time (time/s)

	Plane	Goose	Horse	Eagle
Pixel	643*963	643*963	643*963	643*963
FCM	8.1618	5.4877	6.3925	7.7344
PCNN	21.6294	21.8116	20.2540	21.8268
Proposed method	2.9150	2.9298	1.3152	2.9412

6 Conclusion

In order to solve the problem that the segmentation effect is not good and the amount of computation is too large in the fuzzy C mean clustering, this paper proposes an asynchronous multi-scale processing method. First of all, Gray histogram is used to segment the image roughly and the use spatial relations for further classification, and then propose a multiscale similarity measure method, considering the gray level, position,

information entropy, combining the nonlinear characteristics of the visual system, to the first step of rough classification results by cluster merging. The simulation results show that the algorithm has some improvement in time and segmentation results.

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