International Journal of Multimedia and Ubiquitous Engineering
Vol.10, No.5 (2015), pp.429-436
http://dx.doi.org/10.14257/ijmue.2015.10.5.39

Image Segmentation Using Mean Shift Based Fuzzy C-Means Clustering Algorithm: A Novel Approach

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Abstract

With the fast development of image processing technique, segmentation related issues have gained special attention in the research community. In this paper, an improved FCM combining mean shift algorithm is proposed to improve the segmentation visual effects and efficiency of traditional FCM. Initially, image segmentation into many small homogeneous area using the mean shift algorithm is conducted, segmentation and uniform area, rather than pixels as the new node. Then, image local entropy is adopted to describe the new nodes spatial and gray feature. Finally, an exponential function which is able to well simulate human nonlinear visual reaction was used to measure the similarity between the new node and the cluster center node. The experimental result shows the effectiveness and robustness of our proposed FCM, further potential research is also discussed.

Keywords: *Image Segmentation, Mean Shift, Fuzzy C-means Clustering Algorithm*

1. Introduction

Image segmentation is the basis of image for subsequent processing. Its essence is an image pixel in accordance with certain attributes such as gray scale, color, texture, shape, spatial location, divided into several continuous processes, has a uniform region [1]. In general, Researchers focus on improving certain parameter of an image. These parameters are normally related to some specific feature stated as a foreground other splinter is called background, they generally resemble to the image in a specific and unique nature of the area [2], so the technique of feature extraction is image segmentation. Image segmentation is a process of separating an image into sub area which has different characteristics. Image segmentation is an important part for image analysis, because by which some one extract the feature for further image processing. This technique is used to get the meaningful result, for effective storage as well as fast retrieval of sub image. Image can be called as array of pixel which is arranged in row or column manner, each pixel shows the color at a single point on image. Because of the different segmentation methods, pixel category attribution are also different, strictly control the pixel category attribution is more difficult, so the fuzzy image segmentation method based on the obtained attention. Among them, the most representative method is the fuzzy C-means (FCM) clustering method, its advantage is that less human participation, can achieve automatic segmentation and is widely used, for example, the detection and location of military targets on the sea in order to achieve precise navigation, for the medical image to realize the positioning of tumor and lesion and cutting, recognition and detection and evaluation of the quality of agricultural products such as apple appearance [3-5]. However, the requirement of the segmentation precision and algorithm efficiency is requested more and more high, the traditional FCM algorithm due to the following two significant shortcomings which could not meet with the actual needs: (1) Algorithm uses only gray difference to describe node (pixel) similarity between target segmentation, the object to be susceptible to the complex structure of image features (such as texture, gray)

ISSN: 1975-0080 IJMUE
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interference appear wrong segmentation phenomenon. (2) The algorithm required to examine differences with each node clustering centers, along with the increase of the number of nodes, time-consuming anomaly is bound in practical application. In this case, there have been many improved algorithm, studies of representative: Zhao [6] put forward the kernel generalized FCM fusion algorithm of spatial information, the rational use of pixel neighborhood information space constraints on each pixel, and the objective function was improved, using the distance formula to measure nuclear induced instead of Euclidean distance formula based on, has obtained the good effect in the noisy gray image target segmentation. The literature [7] texture difference in weighted mean and color components are integrated into the standard FCM algorithm in feature, image segmentation, the continuity of the region more accurately than the traditional FCM segmentation algorithm. Document [8] considers the pixels of the image global features of solitary and local homogeneity, starting from the essence of the FCM algorithm to obtain good segmentation results. However, the above algorithms are only from certain feature fusion image set about improving, ignoring the efficiency of the algorithm.

In the traditional FCM clustering algorithm and improved algorithm in various problems, this paper puts forward the fuzzy mean means based on shift (MS-FCM) clustering image segmentation algorithm. Using mean shift algorithm for image pre segmentation, to the pre segmentation of homogeneous regions obtained as a FCM cluster sample set. The introduction of local entropy of image describe image features for each sample, the new feature vector contains both the gray information of the image, but also contains the spatial image information letter. We adopt a novel egg perceive function to simulate the difference of the features. The experimental result indicates the effectiveness and correctness of our proposed methodology. In one way, the proposed algorithm is less time-consuming. In another, our method is able to overcome the interference of complex structure characteristics of background and noise.

2. The Traditional FCM Algorithm

In this section, we briefly describe some basic concepts of FCM. We define the universal dataset for clustering as $X=\{x_1,...,x_N\}$, $B=\{\beta_1,...,\beta_C\}$ denotes the prototypes of C clusters. We define the $U=\left[u_{ij}\right]_{N\times C}$ as a fuzzy partition matrix, where $u_{ij}\in[0,1]$ represents the individual membership of x_i in a cluster with prototype β_j . $\beta_j, x_j \in R^p$, in which P denotes the dimension of the testing data set, $1\le i\le N$ and $1\le j\le C$. The Fuzzy c-means clustering methodology can be finalized through minimizing the following objective function:

$$J_{FCM}(U,B,X)=\sum_{j=1}^{C}\sum_{i=1}^{N}u_{ij}^{m}d_{ij}^{2}(x_i,\beta_j) \tag{1}$$

In the formula 1, the parameter $m>1.0$ represents the weighting exponent on each fuzzy membership and d_{ij} is the Euclidian distance from data vectors x_i forward to the cluster center denoted as β_j . Therefore, we could conduct the following formula:

$$\begin{aligned}&\sum_{j=1}^{C}u_{ij}=1 \qquad \forall i=1,2,...,N.\\ &o<\sum_{i=1}^{N}u_{ij}<N \qquad \forall j=1,2,...,\mathrm{C}.\\ &d_{ij}=\left\|x_i-\beta_j\right\|\end{aligned} \tag{2}$$

The formula 2 will produce the update function as the following:

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$$u_{ij} = \left(\sum_{k=1}^{C} \left(\frac{d\left(x_i, \beta_j\right)}{d\left(x_i, \beta_k\right)} \right)^{2/(m-1)} \right)^{-1} \tag{3}$$

$$\beta_j = \frac{\left(\sum_{i=1}^{N} \left(u_{ij}\right)^m x_i \right)}{\left(\sum_{i=1}^{N} \left(u_{ij}\right)^m \right)} \tag{4}$$

After computing the memberships of all the objects, the new prototypes of the clusters are calculated. The process stops when the prototypes stabilize. That is, the prototypes from the previous iteration are of close proximity to those generated in the current iteration, normally less than an error threshold.

3. Mean Shift Based FCM Algorithm

3.1. The Mean Shift Pre-Segmentation

Mean shift algorithm (renamed as the mean drift [9]) is a kind of density estimation algorithm based on nonparametric kernel function and the kernel function is increasing probability density along the direction of density gradient, the final convergence to the local probability density near the maximum points. While applying mean shit algorithm on the image segmentation assignment, we denote the kernel function to be $G(x)$. Mean shift vector is represented as the formula 5.

$$M_h(x) = m_h(x) - x \tag{5}$$

In which $m_h(x)$ is defined as the following:

$$m_h(x) = \frac{\sum_{i=1}^{n} G\left(\frac{x_i - x}{h}\right) w(x_i) x_i}{\sum_{i=1}^{n} G\left(\frac{x_i - x}{h}\right) w(x_i)} \tag{6}$$

We choose x pixels as seed points, ε as the allowable error, mean shift algorithm according to the following steps to realize image pixel clustering: Step1: Start from the initial node x to calculate the $m_h(x)$, assign the $m_h(x)$ value to x. Step2: Determine the step length and re-calculate the next $m_h(x)$. Step3: If $\|m_h(x) - x\| < \varepsilon$, we mark the node and all through the nodes from its starting point the holiday point the same marking, end of cycle; Otherwise, continue with Step 1 and Step 2, until all nodes are marked. Step4: Merge homogenous area, realize the image segmentation. As shown in figure 1, the number of original image nodes (pixels) is 25×33. We will regard the mean shift every small area as the next step in the process of the segmentation of nodes in the fuzzy c-means clustering algorithm, the node number from 825 to nine. Visible, based on the mean shift to pre segmentation of the image, greatly reducing the number of nodes, for subsequent nodes (area) the image characteristics of clustering speed increase laid a solid foundation.

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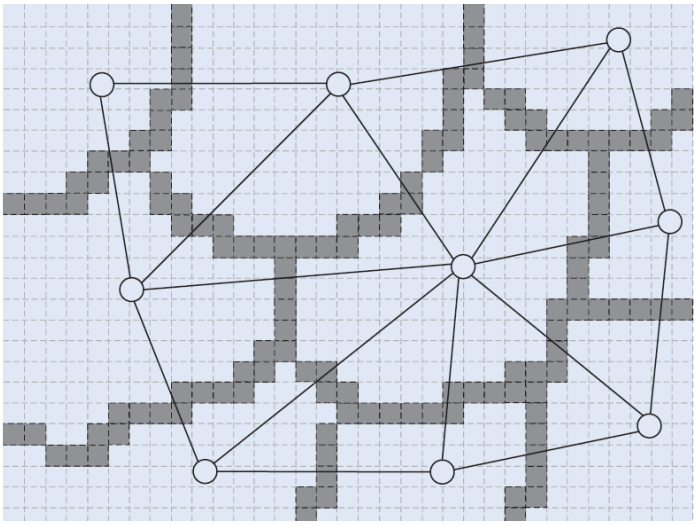

Figure 1. The Mean Shift Pre-Segmentation

3.2. The Image Entropy Characteristics

In order to make full use of the color of the image and local shape information, using the image local entropy of image features is described. Information entropy is given by the Shannon, expressed as a probability distribution function of random variable. Suppose the vector to be $v=\{x_1,x_2,...,x_n\}$. $p_i=P(x_i)$ denotes the probability of the appearance of $x_i \in v$. Therefore, the information entropy of v is:

$$E(v)=-\sum_{i=1}^{n} p_i \log_2(p_i) \tag{7}$$

Normally, image color distribution is un-even and color uneven regional uncertainty is large, color simple small area of uncertainty. Uncertainty of color distribution can be expressed with information entropy, the color of the image histogram as a probability density function. Hypothesis h_i is quantified said color i pixels in the percentage of the whole image [10], therefore image information entropy can be expressed as:

$$E(H)=-\sum_{i=0}^{n} h_i \log_2(h_i) \tag{8}$$

By equation (8), regional spatial structure of the information you can use the information entropy measurement [11] will get every little piece of mean shift the pre-segmentation region (nodes) with the characteristics of a partial information entropy, said the global features of the image can be represented by a set of partial information entropy is zero.

$$A=\{E_{s1},E_{s2},...,E_{sm}\} \tag{9}$$

$s_i(i=1,2,...,m)$ denotes the mean shift segmentation of small area. m represents the total amount of the nodes od the segmented area. Information entropy of different areas ca be denoted as E_{sm} which could be calculated according to formula 9.

3.3. The New Metric Formula

Existing research shows that visual is sensitive to the brightness difference degree change with background brightness is nonlinear. In order to better simulate the visual perception characteristics, combined with the feature of the new node formula, will improve the distance

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From the formula is applied to image segmentation algorithm. The improved similarity measure formula is:

$$\left[d_k(s_i)\right]^2_{new} = 1 - \exp\left(-\beta\left\|E(s_i) - E(v_{k-new})\right\|\right) \quad (10)$$

β denotes the degrees of freedom parameter, which is used to adjust the curvature of the curve. New distance formula meets the standard vector distance, it has stronger robustness for noise, and the function can well simulate the human eye perception of brightness changes [12-16].

3.4. The Flow Chart of MS-FCM Algorithm

Improved algorithm (FCM) MS mainly divided into two parts: the first to pre segmentation of the image, and then will greatly reduce the number of nodes after the pre segmentation image with the improved FCM algorithm was the final segmentation. The flowchart is presented in the figure 2.

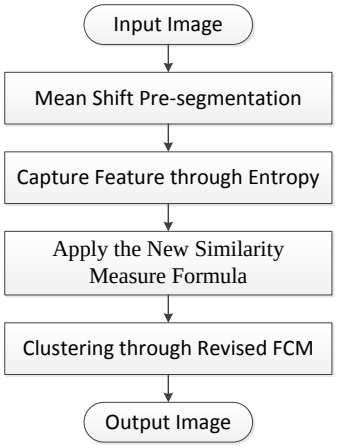


Figure 2. The Flowchart of Our Method

4. Experimental Analysis

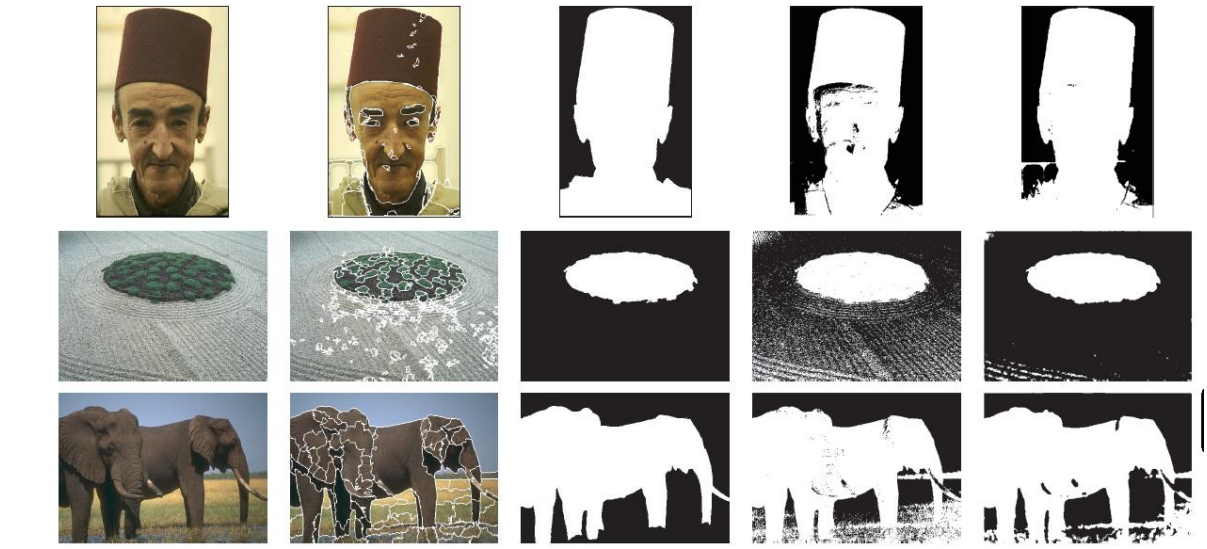
4.1. The Segmentation Performance

Respectively by two experiments verify the algorithm for complex background image and noise image segmentation is effective. On the visual effect of algorithm segmentation, adopt the goal of background of binary classification image test. Respectively expert manual segmentation image and the standard profile with the traditional FCM algorithm, and simulated the cat optic nerve network of PCNN and compared in this paper, the segmentation result of improved algorithm.

(a) (b) (c)

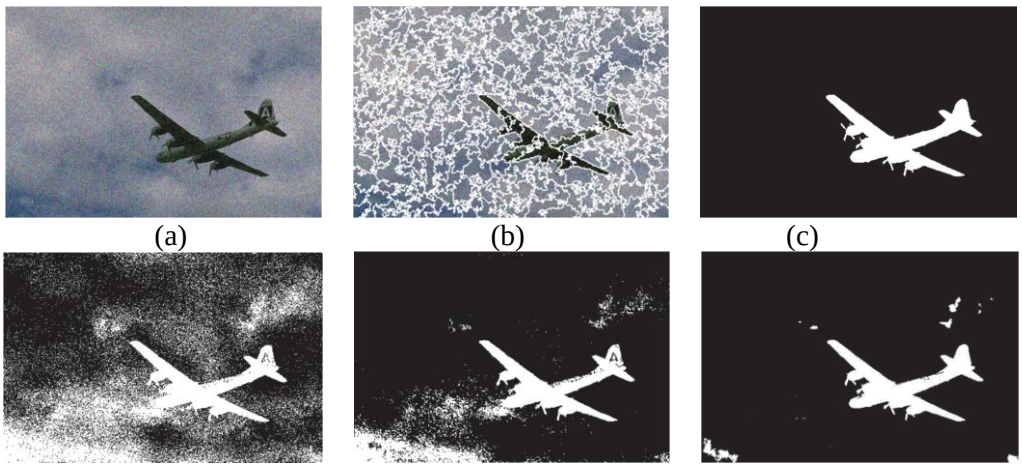
(d) (e) (f)

Figure 3. (a) Original Image, (b) Pre-segmentation, (c) Ground Truth, (d) Traditional FCM, (e) PCNN, (f) Proposed Method



(a) (b) (c) (d) (e)

Figure 4. a) Original Image, (b) Pre-segmentation, (c) Ground Truth, (d) Traditional FCM, (e) Proposed Method



(a) (b) (c)

(d) (e) (f)

Figure 5. a) Original Image, (b) Pre-segmentation, (c) Ground Truth, (d) Traditional FCM, (e) PCNN, (f) Proposed Method

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This article images are from the Berkeley standard image library, the experiment parameter is set to: In the mean shit algorithm, Spatial for 8, Color is 6.5, Minimum Region for 100. PCNN algorithm, n = 16, other parameter Settings see literature [9], the parameters for FCM is: $\delta = 0.0001$, $m = 2$, $c = 2$. Experiments using MATLAB 7.0 programming language implementation, experimental environment for the Intel (R) Core (TM) 2 Quad 2.66 GHz CPU, 3.50 GB of memory of the PC.

Figure 3 (a) is 350 x 446 pixel size of standing on the lawn images of the horse, the horse as a prospect, the lawn as a background, the background contains rich texture information, how to overcome the background interference is a problem. About the prospect of traditional FCM algorithm and PCNN algorithm are not completely overcome the lawn background interference, this paper puts forward the improved algorithm can extract independent target, visual effect and the approximate experts manual segmentation results, which verify the validity of the algorithm in this paper. To join in the plane image with mean zero, variance of Gaussian random noise was 0.05 to verify the algorithm's ability to resist noise (as shown in figure 5). The figure 5 (d) ~ 5 (f), the traditional FCM algorithm and PCNN algorithm susceptible to noise interference and appear false segmentation, this algorithm can accurately separate the target from the background, to suppress the noise effect on the segmentation result.

4.2. The Efficiency of the Algorithm

On the basis of the horse and the plane image segmentation, then select three groups of image simulation experiments to verify the algorithm's efficiency, as shown in figure 4.1 as the original picture, 2 as the pre segmentation results using mean shift, as ideal contour Figure 3, 4 as traditional FCM segmentation results, as using this article 5 (MS - FCM algorithm segmentation result. Table 1 lists the total number of the original image pixels and using the FCM algorithm, PCNN algorithm and the algorithm of the running time. The table 1 shows, MS - FCM algorithm efficiency is superior to PCNN algorithm and FCM algorithm, this is due to the MS - using mean shift the pre-segmentation of FCM algorithm is homogeneous area as a new fuzzy clustering nodes, makes in the image, a substantial reduction in the number of nodes, processing speed is improved obviously.

Table 1. The Run-time Comparison

Image	***HORSE***	***PLANE***	***MAN***	***GRASS***	***ELEPHANT***
SIZE	350×446	481×321	321×481	481×321	481×321
FCM	3.835696	8.287819	6.087706	4.075776	3.670177
PCNN	22.36	22.27	22.02	22.35	22.26
MS-FCM	1.326	3.528	1.054	0. 869	0.631

5. Conclusion and Summary

In order to overcome the traditional FCM clustering method of high time complexity, sensitivity to noise, poor background interference resistance ability of faults, in this paper we put forward the pre segmentation and fuzzy mean value image segmentation for the mean shift clustering segmentation in two stages. First, the application of mean shift algorithm for image segmentation into many homogenous area, with the homogeneous region instead of single pixel points in traditional FCM algorithm; Then, the local entropy of image is used to calculate the new node (blocks) of characteristic; Finally, using a can

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simulate human visual perception of distance measurement formula to measure similarity between the new node. Based on the 5 set of images of the simulation results show that this algorithm combines the advantages of the mean shift algorithm and FCM algorithm, the improved algorithm in segmentation processing speed and ability to resist noise has greatly improved.

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