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A New Image Enhancement Based on the Fuzzy C-Means Clustering

***Abstract**. The enhancement of the infrared dim small target image is a very important pretreatment in automatic recognition of target and infrared target tracking system. The paper proposed a new image enhancement algorithm based on the Fuzzy C-Means clustering. The algorithm conducted cluster analysis on the pixel and gray of the infrared image and increased the image gray level difference between the various objects so as to achieve the enhanced purpose for infrared small target image. The experimental results showed that this algorithm is able to enhance small target image to the maximum extent with ensuring no loss of the target information*

***Streszczenie.** W artykule za[proponowano nowy algorytm poprawy jakości obrazu otrzymanego w podczerwieni bazujący na klastrach rozmytych typu C. Algorytm analizuje piksle i odcień szarości obrazu i rozszerza poziom różnic szarości. Symulacje potwierdziły przydatność algorytmu dla małych zbiorów. (**Nowy algorytm poprawy obrazu w podczerwieni bazujący na rozmytych klastrach typu C**).*

Keywords: infrared image; image enhancement; algorithm; fuzzy C-means clustering
Słowa kluczowe: obraz w podczerwieni, jakość obrazu.

Introduction

Due to the constraints of the sensitivity, resolution, noise and other features of infrared imaging devices and the existence of radiation and other factors affect between the objectives and the surrounding environment, the image acquired by the Infrared imaging system is not as rich level as the visible light image. Infrared images showed more images noisy, low contrast. Especially in the infrared small target, they often were submerged in a large background, which brought great difficulties to the identification and extraction of the target. So it is necessary to conduct the enhancement of the infrared images obtained. As the edge gradient of the target and the background was not large and the edge ambiguity was great, in general, the enhancement effect of a variety of the image enhancement methods used in the past was not obvious.

Based on the gray distribution feature of the infrared dim small target image, the paper proposed a new image enhancement algorithm based on the Fuzzy C-Means clustering. The algorithm conducts first the cluster analysis of the infrared image, gives then each category gray value so as to increase the edge gradient of the target.

Fuzzy C-means clustering algorithm

Fuzzy C-means clustering is an unsupervised statistical method. It does not require training samples. By means of the iterative, it optimizes the objective function used to represent the image pixel similarity with the C class center and obtains maximum value, resulting in optimal clustering [1, 2]. The basic idea of the fuzzy C-means clustering algorithm is as follows: Class the data set $X=\{x_1, x_2, \dots, x_n\}\in R^{pn}$ into C classes. If set the membership of any samples x_k in the X for the i-th class as u_{ik}, then classification results can be a fuzzy membership matrix $U = \{u_{ik}\}\in R^{cn}$. Fuzzy C-Means clustering is achieved by minimizing the objective function Jm (U, V) about the membership matrix U and cluster center V:

$$J_m(U,V)=\sum_{k=1}^{n}\sum_{i=1}^{c}(u_{ik})^m d_{ik}^{\,2}(x_k,v_i) \tag{1}$$

Here, $U=\{u_{ik}\}$ is for the membership matrix, $V=\{v_1, v_2, \dots, v_c\}$ is for the set of C cluster center points, $m\in[1,\infty]$ is for the weighted index. When m=1, the fuzzy clustering retrogrades as the hard C-means clustering. The reference [3, 4] showed that the best choice range of m is [1.5, 2.5]. Usually m = 2 is the ideal value.

The distance from the k-th sample to the i-th class center is defined as:

$$d_{ik}^2(x_k,v_i)=\|x_k-v_i\|=(x_k-v_i)^T A(x_k-v_i) \tag{2}$$

Here, A is positive definite matrix P×P, when A is the unit matrix, the distance is the Euclidean distance. Fuzzy C-means clustering optimizes the objective function as shown in the formula (1) through repeated iterations, which performs the following steps:

(1) Initialize the cluster centers $V=\{v_1, v_2, \dots, v_c\}$;
(2) Calculate the membership matrix:

$$u_{ik}=[\sum_{j=1}^{c}(\frac{d_{jk}(x_k,v_j)}{d_{jk}(x_k,v_j)})^{2/(m-1)}]^{-1}, k=1,2,\dots,c \tag{3}$$

(3) Update cluster centers and calculate $J_m(U,V)$;

$$v_i=\frac{\sum_{k=1}^{n}(u_{ik})^m x_k}{\sum_{k=1}^{n}(u_{ik})^m}, i=1,2,\dots,c \tag{4}$$

(4) Select the appropriate matrix norm (such as, Euclidean distance), compared $J_m(k)$ with $J_m(k+1)$, if$\|J_m(k+1)- J_m(k)\|<\varepsilon$ then stop iteration; otherwise $k = k+1$, go to (2).

When the algorithm converges, we get various the centers of the various classes and membership values of various samples belonging to various classes, thus completing the division of fuzzy clustering. If necessary, you can also conduct to remove fuzzy of the results of fuzzy clustering, that is, you can use certain rules divides the fuzzy clustering classification into the deterministic classification. Generally the maximum membership principle is used: if $u_{i_0 k} = \max_{1 \le i \le c}\{u_{ik}\}$, then the sample x_k Belongs to the i_0-th class. Therefore, in Practical application, the formula (4) can also be expressed as follows: If the number of the different points in the membership degree sets of the calculation of the two time adjacent is less than a certain value, then the iteration ends.

Improved fuzzy C-means clustering algorithm

Clustering Analysis on the Infrared Dim and Small Target Image：The key of the infrared image enhancement is to increase the gradients of the junctions of the target and background gradients. Use the C-means clustering method to conduct the gray classification of the image[5], Re-assignment the gray value of each class so as to enhance the gray difference between various classes. In the ideal case, the target should be divided into one class [6, 7]. However, it is almost impossible for the dim and small target. Generally speaking, the gray-scale of the dim and small target accounts for fewer pixels, gray difference between the target pixel and surrounding other pixel is minimal. Therefore, it is easy to class target pixel and surrounding other pixels of the similar gray into the same class so as not to achieve the purpose of enhancing the target. To achieve the classification of the dim and small target classification, the only way is to increase the number of the classes [8, 9]. However, to increase the number of categories can make the clustering speed slow down. In addition, due to the presence of noises, even if the number of categories was raised higher, the noises can only be divided into different classes, the target is difficult to be separated from them[10]. This is because the noise and the background and objectives are very different from the target in the gray levels. Clearly, to directly conduct the gray clustering method for the and small target is not feasible. In this paper, the standard C-means clustering method was improved. Firstly, the infrared image was conducted the histogram equalization so that the overall gray of the image should be evenly distributed. Secondly, the peak value of the histograms was used as the cluster center value. The peak number was used as the number of classes[11]. The gray images were carried out the cluster. Then, the gray value of the cluster centers were compared and were analyzed. As the general target area share more pixels and the gray difference between the goal and background for these images is smaller, therefore, if the pixel number of the certain class is less and its central gray has larger difference from the central gray of other classes, then this class does not contain the target, whereby it can be removed. The remaining classes will be merged. Then according to the original classification number[12], the re-clustering was carried out, and so on, until the difference between each class and other classes in the gray of the cluster centers is little. Even if the dim and small target is mistakenly divided into several categories, the difference between the target class and other classes in the gray is not large [13, 14], so the target class can not be excluded.

Algorithm Steps：A gray image is usually has a certain density distribution around the certain number center points in the gray space [15]. The points located in the vicinity of the center point constitute a subset which is similar in the gray. Here are the specific steps for conducting clustering in all areas of the infrared dim and small target image clustering.

(1)Transform $M \times N$ image into a one-dimensional array, establish a data set $X = \{x_1, x_2, \ldots, x_n\} \in R^n$, here, $n = N \times M$, x_i is the gray value of the i-th pixel in the image.

(2) The histogram equalization processing of the image [16]: Assume it can be divided into n_p levels. The i-th level shares the gray-level ratio of $T_j/256$, T_j is for the gray of the i-th level, $j \in n_p$.

(3) Calculate the average the gray value of the whole image:

$$t_{avg} = \frac{\sum_{r=1}^{n} f_r}{M \times N} \tag{5}$$

Here, f_r is the gray of the i-th pixel.

(4) Clustering initialization

The image data was carried out the clustering processing, classification number $C=n_p$, the initial center value of each class $V = \{T_1, T_2, \ldots, Tn_p\}$, the pixel number of each class is r_j. Thus, by hierarchical clustering, the data set X whose sample size is n was divided into n_p subsets, that is, $S = \bigcup_{t=1}^{n_p} s_t$.

(5) Calculate the cluster distance

Since the gray of the pixel points within the each subset is closer, so the distance from $x_i \in S_k$ to point T_i can be approximately expressed by the distance from the center T_k of the S_k to T_i, namely:

$$d_{ik}^2(x_k, T_i) = d_{ik}^2(T_k, T_i) = \| T_k - T_i \|^2 \tag{6}$$

(6) Calculate the membership, updating cluster centers

The size of the fuzzy matrix U changes from the original n×c into n×n_p. The calculation formula of the membership is still the formula (3), the calculation formula of the n_p cluster centers changes from the formula (4) into the follow the formula (7):

$$J = \sum_{0}^{\infty} A^2 \sin \omega t + \int_{0}^{\infty} \sqrt{B_1^2 + C_2^2} + \frac{4\pi}{\mu_0} \int_V \frac{J \times r}{r^3} dv \tag{7}$$

The calculation formula of the objective function changes from the formula (1) into the follow the formula (8):

$$J_m(U, V) = \sum_{k=1}^{n} \sum_{i=1}^{n_p} (u_{ik})^m d_{ik}^2(T_k, T_i) \tag{8}$$

(7) Select the appropriate matrix norm (e.g. Euclidean distance), compared $J_m(k)$ with $J_m(k+1)$, if $\|J_m(k+1) - J_m(k)\| < \varepsilon$, then stop iteration; otherwise k=k+1, go to step (5).

(8) Compare the cluster center value of each class. If the cluster center value of the certain class is T_f, $T_f > T_j$ or $T_f < T_j$ and the number of pixels contained in the class is r_f, $r_f < r_j$, then $T_f = t_{avg}$. Here, $j = 1, 2, \ldots, m$, T_j is for the gray value of any class, tavg is for the gray value of the entire image. Therefore, the way that the pixel gray value of the class T_f to be eliminated is set into the average gray value of the whole image can make the class removed.

(9) n_1 times continuously perform the step (4). If the noise of the image is larger, n_1 value to be taken.

(10) Determine whether the target is clear, Using the artificial judge, if not ideal, return to the step (5); Otherwise, complete image segmentation and finish the algorithm.

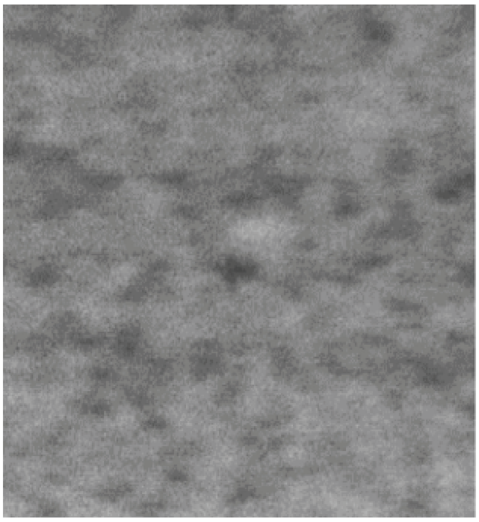

Fig.1. Original image

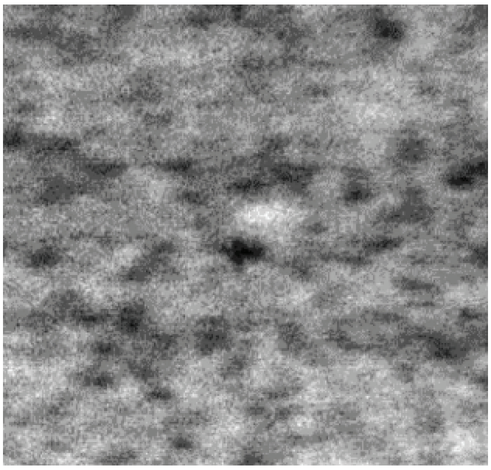

Fig.2. The enhanced images of the direct gray clustering

Determine the Parameters of the Algorithm：For the dim and small target, the difference between the target gray and the surrounding gray is necessarily small. In the classification, they can be easily divided into a class. If a target area is divided into a class in the beginning classification, it cannot be called a dim target [17]. Therefore, this algorithm is very safe for the dim and small target. The main difficulty of this algorithm is to determine m and n_1. Experiments showed that the value of m is close to the image histogram. If the gray of the histogram is too concentrated, the value of m should be taken smaller; the contrary, the value of m should be taken larger. The value of n_1 is close to the noise of the image. If the noise is more, the value of n_1 should be made larger; the contrary, the value of n_1 should be taken smaller. The disadvantage of this method is that it is possible to have some damage on the background information, especially when the difference between background and the target in the gray is large. The purpose of processing the infrared images is the precise positioning for the outline of the target, so this algorithm does not affect the positioning accuracy of the image.

(1) Determine the value of n_1

The value of n_1 determines the number of the minimum point class to be eliminated after classification each time. This value is selected too small, the number of the minimum point class to be eliminated each time small. If this value is selected too large, the target area is easily removed. The experience has shown that it is more appropriate to take value of n_1 as one-tenth of the total class value m.

(2) Determine the value of m

The smaller value of m is, the faster the speed of the system enhancement is, but the slower the enhancement effect is. If $m \approx n_1$, it is easy to remove the target area. The greater the value of m is, the slower the speed of the system enhancement is, but the faster the enhancement effect is. Experience has shown that: the number of categories is best able to meet each class to take $M \times N/30$ pixels.

Experimental results

To verify the effectiveness of the algorithm, we conducted comparative experiment of the algorithm with standard C-means algorithm. Figure 1 is for the dim and small target image (the target is in the center of frame) collected by the photoelectric theodolite. The contrast of the target and background in the image is not obvious, artificial identification of the target is very difficult. Figure 2 is for the image enhancement of the direct gray clustering. Although a certain increase reached, the outline of the target boundary was vague and not completely was separated from the background. Figure 3 is for this improved algorithm. First the histogram equalization processing of the original image was carried out. Here, the number of histogram classification and mean number of clusters were taken to be 30. The value of n_1 was taken to be 3. Figure 3 can be seen, target and background can already be clearly distinguished out.

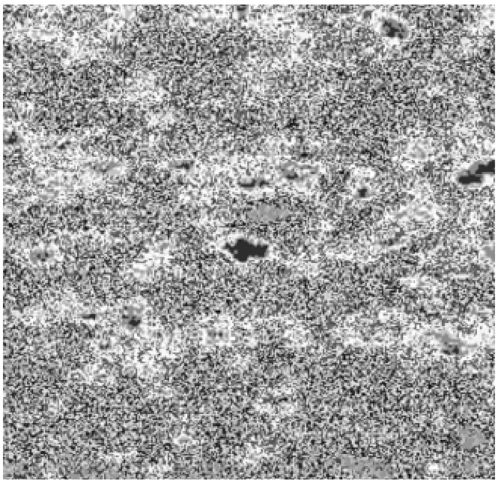

Fig.3. The enhanced images of the fuzzy C-means clustering

Conclusion

Arming at the infrared dim and small contrast degree being low and the artificial identify of the target image being difficult, we proposed a technique based on fuzzy C-means clustering algorithm for image enhancement. A large number of the image data processing experiments showed that the image enhancement effect of the algorithm is obvious. The algorithm can enhance the gradient value of the gray in the border region between the target and background under the condition of keeping the target boundary contour not changing. It has a certain noise suppression effect. It can be applied to the enhancement processing of the very weak infrared target image.

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