Two Improved Fuzzy Enhancement Algorithm based on Pal & King

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Abstract

The source images obtained from information input system usually contain a variety of noise and distortion,which will greatly affect the image quality. Therefore, before analysis of the image, you must first enhance the image quality. A typical enhancement algorithm based on fuzzy technology is Pal&King algorithm. In order to solve the defects of Pal&King, two schemes are presented in this paper. Using the improved algorithms of image processing can provide more detail, and have good visual effect.

Keywords

Enhancement Algorithm; Fuzzy Technology; Pal&King Algorithm.

1. The basic concept of fuzzy sets

Fuzzy set [1-5] is described by the membership function, the key of fuzzy sets is to accurately determine the membership function[6-9].

For fuzzy set A in universe U, specify a map from U to $[0,1]$:

$$\begin{aligned}&\mu_A : U \to [0,1]\\&u \to \mu_A(u \in [0,1]\end{aligned} \tag{1}$$

where μ_A is the membership function for fuzzy set A. $\mu_A(u)$ is the membership u relative to A.

2. Image enhancement based on fuzzy technology

2.1 Fuzzy feature plane

From the perspective of fuzzy sets, a $M \times N$ picture with L gray levels,can be seen as a fuzzy set. Each element in the set have a membership related to specific gray level.This fuzzy set is called equivalent fuzzy set, is the fuzzy character plane of a image. Corresponding fuzzy matrix recorded [10-12]as X:

$$X = \bigcup_{m=1}^{M} \bigcup_{n=1}^{N} \frac{\mu_{mn}}{X_{mn}} \tag{2}$$

Where $\mu_{mn} \in [0,1]$ means the membership function of gray level X_{mn} of pixels (m,n),related to a specific gray level X_k.

2.2 Pal&King algorithm

In the mid-80s, Pal&King [13-14] propose a membership function, using enhancement algorithm based on fuzzy technology to contrast enhancement. The method is:

First of all,map the image from space to fuzzy feature domain: map the Image as a fuzzy matrix X:

$$X = \bigcup_{m=1}^{M} \bigcup_{n=1}^{N} \frac{\mu_{mn}}{X_{mn}} \tag{3}$$

In the formula, μ_{mn} / X_{mn} means the membership function of gray level x_{mn} of pixels (m,n),related to a specific gray level X_{mn}. Usually we choose maximum gray level $X_{\max}$ as X_{mn}.Then define membership function as follows:

$$\mu_{mn} = G(x_{mn}) = (1 + \frac{X_{\max} - X_{mn}}{F_d})^{-F_e} \tag{4}$$

F_d is reciprocal fuzzy factor while F_e is Exponential fuzzy factor.

Then use the following nonlinear transformation T_r in fuzzy space:

$$T_r(\mu_{mn}) = \begin{cases} 2(\mu_{mn})^2 & 0 < \mu_{mn} < 0.5 \\ 1 - 2(1 - \mu_{mn})^2 & 0.5 \le \mu_{mn} \le 1 \end{cases} \tag{5}$$

By this way, the image was fuzzy enhancement.

Fuzzy enhancement operator generated another fuzzy set based on the previous fuzzy set G.

$$\mu'_{mn} = T_r(\mu_{mn}) = T(T_{r-1}(\mu_{mn})), r = 1,2,\ldots \tag{6}$$

Where T_{r-1} means repeated calls of T.

Finally,use inverse transform G^{-1},translate enhanced image from the fuzzy space back into data space.

2.3 The defect of Pal. King algorithm

The defect of Pal. King algorithm [15-17] is defined that: When $X_{mn} = X_c, T(x_c) = 0.5$, x_c is treated as crossover point:

$$T(x_c) = (1 + \frac{x_{\max} - x_c}{F_d})^{-F_e} = 0.5 \tag{7}$$

Thus get:

$$F_d = \frac{x_{\max} - x_c}{2^{1/F_e} - 1} \tag{8}$$

Parameter F_d is determined by the x_c and F_e.When x_c and F_e are seted, we will get corresponding curves between μ_{mn} and x_{mn}, as Fig. 1.shown below:

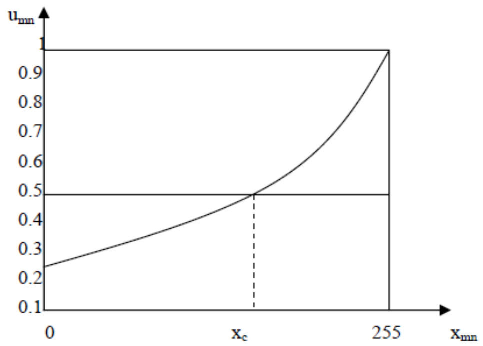

Fig.1 corresponding curves between μ_{mn} and x_{mn}

Pa1.King algorithm has the following defects [18-23]:

(1)After T_r transformation, will cause in a significant number of low gray scale value cutting to 0 in the original image, This will damage the edge of a low gray value information, also affected the quality inspection, not only that, the transform form of T_r is complex.

(2) G and G^{-1} includes complex floating-point operations, thus has large computation.

(3)Repeated iteration is to enhance the image repeatedly. However, when the number of iterations is greater than four, the details of the edge are disappeared. Many experiments show: the effect of one time iterations and twice, three times iterations was no significant difference.

(4)Formula F_d and F_e are very complex, while the select of F_d and F_e decided to image processing results, thus there exits a problem of find the optimal parameters.

3. Two improved fuzzy enhancement algorithm

3.1 Membership function optimization

In order to solve the shortage of algorithm, we first find the threshold between background and objectives, then define fuzzy matrix element according to different regions. By this way, we can improve the first defect as stated above. After this, we enhance the image by fuzzy technology. If the enhancement is not so good, iterated to get the best membership threshold and improved enhancement result.

The algorithm steps are as follows:

Step One: calculate the appropriate threshold. There are many ways to calculate threshold [24]. Iterative algorithm is used here[25-26]. First of all, take the middle value $X_{\max}/2$ of image gray level as initial threshold X_0(Suppose the total number of gray levels is $X_{\max}$), then do iteratives by the following formula:

$$X_{i+1} = \frac{1}{2}\left(\frac{\sum_{k=0}^{X_i} n_k \bullet k}{\sum_{k=0}^{X_i} n_k} + \frac{\sum_{k=X_i+1}^{X_{\max}} n_k \bullet k}{\sum_{k=X_i+1}^{X_{\max}} n_k}\right) \tag{9}$$

where n_k means the number of pixels gray value of k, iterative until $X_{i+1} - X_i \le allow$, $allow$ means the difference before and after iteration. According to the different image we can make appropriate adjustments. The smaller $allow$ is, the more the median threshold tends to. Get the end threshold X_i as threshold, denoted as X_T.

Step Two: Define a new membership function

$$u_{mn} = G(u_{mn}) = \begin{cases} \dfrac{x_{mn}}{X_T} & x_{mn} \le X_T \\ \dfrac{x_{mn}}{X_{\max}} & x_{mn} > X_T \end{cases} \tag{10}$$

Where x_{mn} is original data matrix, X_T is threshold. Different from Pal&King, when we define fuzzy matrix element, this algorithm take X_T as dividing line, define membership function separately. In this way, low gray level information of image lossed little, also the third step of the fuzzy enhancement achieve better results.

Step Three: Enhanced Image. Actually, it is in the fuzzy character plane of image, do non-linear transformation [27] to μ_{mn}.As a result, increased μ_{mn} that greater than μ_c and reduced μ_{mn} that less than μ_c.Use the following enhancement operator:

$$\mu'_{mn} = T_r(\mu_{mn}) = T_l(T_{r-1}(\mu_{mn})) \tag{11}$$

where,

$$T_l = \begin{cases} 2(\mu_{mn})^2 & 0 \le \mu_{mn} \le \mu_c \\ 1-2(1-\mu_{mn})^2 & \mu_c \le \mu_{mn} \le 1 \end{cases} \tag{12}$$

Step Four: Inverse transformation according to the following formula:

$$x'_{mn} = G^{-1}(\mu'_{mn}) = \begin{cases} \mu'_{mn} \cdot X_T & x_{mn} \le X_T \\ \mu'_{mn} \cdot X_{\max} & X_T \le x_{mn} \le X_{mn} \end{cases} \tag{13}$$

3.2 Improve the enhancement operator

According to our analysis above, we give the following improved algorithm based on Pal&King. The detailed algorithm is as follows:

(1)To reduce the computational load, we define a simple and effective membership function.

$$\mu_{mn} = G(x_{mn}) = \sin\frac{\pi x_{mn}}{2X_{\max}} \quad (14)$$

This membership values are found in $[0,1]$, and saved the low gray value edges after processing.

(2)Enhanced Image. Do nonlinear transformation repeated.

$$\mu_{mn}^{'} = T_r(\mu_{mn}) = T(T_{r-1}(\mu_{mn})) \quad (15)$$

where $T_r(\mu_{mn}) = (\sin(\pi(\mu_{mn} - 0.5)) + 1)/2$.

This transformation increased μ_{mn} that greater than 0.5 and reduced μ_{mn} that less than 0.5.

(3)Mapping the image from the fuzzy domain to space domain

Inverse transformation using the formula as followings and get gray value of every pixel in the enhanced image:

$$x_{mn} = \min + (x_{\max} - \min) \times \arcsin(\mu_{mn})^{\sqrt{r}} \times \frac{\pi}{2} \quad (16)$$

4. Experimental results

Do simulation test with figure of Lena .Compared two improved algorithms with gray level transformation algorithm, histogram equalization algorithm and Pal&King algorithm. The results are as follows.

a .Original image

b. Dealed with gray level transformation algorithm

c. Dealed with histogram equalization algorithm

d. Dealed with Pal&King algorithm

e. Dealed with the first improved algorithm f .Dealed with the second improved algorithm

Fig.2. The result of simulation test

The aim of image enhancement are: (1) Improve the visual effect and the clarity of the image components.

(2)Make the image more suitable for computer processing. Analyze these results, we can distinguish the advantages and disadvantages by vision. Histogram equalization method is obviously not very strong adaptability. The two improved algorithms achieved good results.

5. Conclusion

Simulation results shows that the first improved algorithm overcome the shortcomings of Pal& King and reduce the computational. In addition, we can extend to multi-threshold situation by modifing the second and four step.

While the second improved algorithm has advantages of quick, convenient, excellent performance, etc. It is a more practical, convenient image processing algorithms. At the same time, it accelerates the choice of the optimal parameters, ensures the quality of enhanced image, and improved the feasibility and efficiency.

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