Research on Image Fuzzy Enhancement Algorithm with Tanh Operator

Xiwen Liu

Department of Electronic & Electrical Engineering, Zhaoqing University, Zhaoqing, Guangdong Province, China
*Corresponding Author Email: liuxiwen1111@163.com

Abstract. Improvements are proposed in this paper to overcome the drawbacks of traditional fuzzy enhancement algorithms. Tanh operator is used as membership function, and fuzzy enhancement function are made up of simple power functions, and the image is divided into two regions by adaptive segmentation method, one is high grey region, the other is low grey region, pixels in one region are enhanced, and pixels in the other region are reduced. Simulation results show that this algorithm has good ability to increase image’s contrast, and it is a simple and efficient way to enhance blur edges.

1. Introduction

Such problems as the inaccuracy and uncertainty often appear in image processing, and this phenomenon is called image fuzziness. Therefore, fuzzy sets theory had applied for image processing and recognition by many scholars. An fuzzy algorithm for image enhancement was first brought out by Pal and King in 1983[1], it is applied to medical image processing and pattern recognition, and good results were gotten. But this algorithm also has such drawbacks as over enhancement, long time cost, etc. For solving these problems, many improved algorithms are researched and good effects are acquired[2-6]. So, the image fuzzy enhancement technology is worthy of research and promotion, good results are often gotten when fuzzy set theory is applied for image processing.

Further research on image fuzzy enhancement are carried out in this paper, an novel membership operator and fuzzy enhancement functions are proposed to get better effect.

2. Fuzzy Enhancement Algorithm of PAL

2.1. Feature Plane of Fuzzy Image

Suppose there is an two-dimensional image, and its size is \( M \times N \), its maximal grey level is \( L \). Therefore, it can be looked as fuzzy pixels sets, expressed as follows:

\[
X = \begin{bmatrix}
    p_{11} & p_{12} & \ldots & p_{1N} \\
    X_{11} & X_{12} & \ldots & X_{1N} \\
    p_{21} & p_{22} & \ldots & p_{2N} \\
    X_{21} & X_{22} & \ldots & X_{2N} \\
    \vdots & \vdots & \ddots & \vdots \\
    p_{M1} & p_{M2} & \ldots & p_{MN} \\
    X_{M1} & X_{M2} & \ldots & X_{MN}
\end{bmatrix}
\]  

(1)
In equation (1), $X_{ij}$ is the pixel $(i, j)$ value, $p_{ij}$ is the membership level of pixel $(i, j)$, $p_{ij} \in [0, 1]$, the fuzzy feature plane is consisted of $p_{ij}$, $p_{ij}$ can be gotten by fuzzy membership function, various membership functions have been brought out for getting good results. The following membership function was defined by Pal and King.

$$p_{ij} = F(X_{ij}) = [1 + \left(\frac{(L-1) - X_{ij}}{F_d}\right)]^{-F_c}.$$  

(2)

In equation (2), $F_c$ is often set equal to 2. Pal membership function is shown in figure 1, as the minimal value of $p_{ij}$ is greater than zero, over-enhancement result will often come into being.

![Figure 1. Curve of Pal and King membership function](image)

2.2. Fuzzy Membership Level Transformation

Pal and King used the following equations to transfer fuzzy membership level $p_{ij}$ for increasing image’s contrast.

$$p_{ij}^* = I_r(p_{ij}) = I_1(I_{r-1}(p_{ij})) \quad r = 1, 2, 3, 4, \ldots$$  

(3)

And,

$$I_1(p_{ij}) = \begin{cases} 2 & 0 \leq p_{ij} \leq 0.5 \\ 1 - 2(1 - p_{ij})^2 & 0.5 < p_{ij} \leq 1 \end{cases}$$  

(4)

Pal and King used equation (3) for further image contrast increasing. With the cycle count $r$ reaching to infinity, an two-value image will come into being. In the fuzzy enhancement algorithm of
Pal and King, the pivotal point $P_c$ is set to 0.5, in some images, this value may not be suitable, therefore, good results sometimes can not be gotten with Pal and King algorithm.

2.3. Fuzzy Membership Level Inverse Transformation
The following is the inverse transfer equation brought out by Pal and King.

$$X'_{ij} = F^{-1}(p'_{ij}) = L - 1 + F_d \left[1 - \left(\frac{p'_{ij}}{E_r}\right)^{\frac{1}{L}}\right]$$

(5)

3. Novel Fuzzy Enhancement Algorithm
Firstly, the membership level function is reconstructed, it is shown in figure (6). In Pal and King algorithm, the enhancement result has relations with pivotal point $P_c$, while novel membership function has no relation with $P_c$.

$$p_{ij} = F(X_{ij}) = \tanh(x) = \frac{e^x - e^{-x}}{e^x + e^{-x}}$$

(6)

In above equations,

$$x = \begin{cases} 
K \left(\frac{X_{ij} - X_T}{L-1-X_T}\right) & \text{for } X_T < X_{ij} \leq L-1 \\
K \left(\frac{X_{ij} - X_T}{X_T}\right) & \text{for } 0 \leq X_{ij} < X_T 
\end{cases}$$

(7)

In equation (7), $L$ is maximal grey level, $X_T$ is the pivotal point gotten by image adaptive segmentation method. $K$ is the amplification factor, $x \in [-K, K]$. Figure 2 shows the curves of equation (6) With various $K$, several features can be gotten.

Figure 2. Curves of membership function
Firstly, the grey levels are mapped to interval \((-1, 1)\), that is different from Pal fuzzy feature plane, the bigger is \(K\), the mapped interval is nearer to \([-1, 1]\). Secondly, the whole function is continuous, it is in favour of preventing the membership level from changing abruptly to make the image over enhanced. Finally, \(\tanh\) function is used to calculate membership level, in the interval \([0, X_T]\), the membership level \(p_j\) is concave function, and it is less than zero; while in the interval \((X_T, L-1)\), \(p_j\) is convex function, and it is bigger than zero. Therese are helpful for increasing the contrast of image’s background and foreground.

Then, the fuzzy enhancement operator in equation (4) is reconstructed, equation (4) can be improved as follows.

\[
p_j' = \begin{cases} 
-\left(\langle p_j \rangle^\alpha \right) & p_j \leq 0 \\
\left(\langle p_j \rangle^\alpha \right) & p_j > 0 
\end{cases} \quad \alpha > 0
\] (8)

Figure 3 shows the curves with various \(\alpha\) in equation (8). Obviously, \(p_j' \in [-1,1]\). When \(\alpha \in (0,1)\), the \(p_j\) less than zero is decreased by this operator, and the \(p_j\) bigger than zero is increased by this operator; When \(\alpha = 1\), \(p_j' = p_j\); When \(\alpha > 1\), the \(p_j\) less than zero is increased by this operator, the \(p_j\) bigger than zero is decreased by this operator. Additionally, the whole function is smooth, which is helpful for strengthening the edges without over enhancement.

![Figure 3. Fuzzy enhancement operator curves with various parameter \(\alpha\)](image)

By inverse transformation, the enhanced image can be acquired; Equation (9) shows the inverse equation. They are consist of simple power functions.

\[
X'_j = \begin{cases} 
\frac{p_j'(L-1-X_T) + X_T}{p_j'} & p_j' \geq 0 \\
\frac{p_j'X_T + X_T}{p_j'} & p_j' < 0 
\end{cases} 
\] (9)

In equation (9), \(L\) is often set to 256, and \(p_j' \in [-1,1]\), it can be seen that \(X'_j \in [0,255]\). Therefore, the phenomenon of losing grey level will not appear when using this novel algorithm.
4. Experiment and Analysis
Blur Lena image is selected as experiment subject. And the novel fuzzy enhancement algorithm brought out in this paper and Pal algorithm are used for testing respectively. All of the algorithms are programmed with Matlab. In the following figures, r is enhancement times.

![Blur Lena image](image1)

![Enhanced image](image2)

**Figure 4.** Blur Lena image and enhanced image by using Pal and King algorithm (r=2)

In figure 4(a), the original image of Lena is a little fuzzy. In figure 4(b), the enhanced image by using traditional Pal and King algorithm does not have good contrast. Therefore, the results when applying novel algorithm in this paper for fuzzy enhancement are as follows.

![Enhanced image](image3)

**Figure 5.** Enhanced image by using novel algorithm (K=2, r=1)

![Enhanced image](image4)

**Figure 6.** Enhanced image by using novel algorithm (K=3, r=1)

![Enhanced image](image5)

**Figure 7.** Enhanced image by using novel algorithm (k=4, r=1)

![Enhanced image](image6)

**Figure 8.** Enhanced image by using novel algorithm (k=8, r=1)

Figure 5-8 are images by using the novel algorithm presented in this paper with various parameters r, $\alpha$ and K. Obviously, the image’s contrast can be increased much by using the novel algorithm than using traditional Pal and King algorithm.
In figure 5, it can be seen that when \( r=1, K=3, \alpha=1.0,0.8 \) the enhancements are good, and the image edges are very distinct; when \( \alpha=0.5 \), the image is near to two-value image.

In figure 6, when \( K=3, \alpha=2.0,1.0,0.8 \) and 0.2, the enhancement results are good; It can be seen that figure 6 has better enhancement than figure 5; Therefore, parameter K should not be too small, it can be explained in figure 2, when K is smaller, the range of \( P^u \) is farther away from the interval [-1 1].

In figure 7, K is changed to 4. Compared to figure 6, the enhancement results are better. The image contrast increase obviously and image edges become more distinct. Therefore, when the novel algorithm is used for image fuzzy enhancement, the parameter K should not be too small.

In figure 8, K is changed to 8. The result images contrast increase obviously and image edges become more distinct. But compared to figure 7, the enhancement results are all near to two-image.

In above experiments, the cycle count \( r \) is set to 1, change the cycle count \( r \) to 2, and keep the other parameters same with figure 7, experiment result are shown in figure 9.

In figure 9, K is set to 4 as in figure 7, the cycle count \( r \) increases to 2, it can be seen that the enhanced results are nearer to two-value image when parameter \( \alpha \) decreases than in figure 7; When \( \alpha \) is large, over enhanced image will come into being. That is to say, good enhancement effects can be gotten within one time.

Therefore, the algorithms presented in this paper can overcome the shortcomings of traditional fuzzy enhancement algorithm; Other more, the algorithms have rich parameters for adjusting to get good results.

![Figure 9. Enhanced image by using novel algorithm(k=4, r=2)](image)

5. Conclusion

In order to overcome the drawbacks of traditional fuzzy algorithm, tanh membership level operator and simple power functions are proposed.

Experiment results show that the image contrast will be increased greatly, and the image edges will become more distinct when the novel algorithm is applied for enhancement.

This algorithms have rich parameters for adjusting, it is easy to adjust some parameters for getting better enhancement results. So, the proposed algorithm in the paper is an good method for fuzzy image enhancement.

6. References

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