Image Enhancement Using FUZZY Set

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Abstract. In this paper, FUZZY set is used to deal with image enhancement problems of some uncertain and inaccurate image. The traditional image enhancement method like histogram modification, image smoothing, image sharpening in verse filters and wiener filter for inaccurate and uncertain image is undesirable. As fuzzy system is capable of representing diverse, non-exact, uncertain and inaccurate knowledge of information, it has attracted the attention of for image enhancement. The generalized enhancement algorithm proposed by Dong Liang Peng and Tie-Jun-Wu in 2002 [1] is not suitable for images having very less gray values, lower contrast, more uncertainly and inaccuracy. A novel approach to generalized image enhancement using fuzzy set is proposed in this paper to overcome the problem.

Keywords: FT · Fourier transform · FUZZY set · Membership · FE · Fuzzy enhancement method · GT · Gray transformation

1 Introduction

The improvement of pictorial information for human interpretation and processing of scene data for autonomous machine perception are the root application areas that has shown interest in image processing filed a decade ago. Vision is the foremost trusted source of information compared to other human perception, and image in the basic container of any pictorial information. The two broad categories of image enhancement are,

- Spatial domain methods based on direct manipulation of pixel
- Frequency domain methods [2, 3] are based on modifying the Fourier transform of an image

Fuzzy image processing approach is the collection of how to understand, represent and process the image, their segmentation & features as Fuzzy set. Fuzzy image processing has three main stages: image fuzzification, modification of membership values and image Defuzzification as given in Fig. 1.

The main reason for using fuzzy image processing is

(a) It is a powerful tool for knowledge representation and process.
(b) It can manage the vagueness and ambiguity efficiently.

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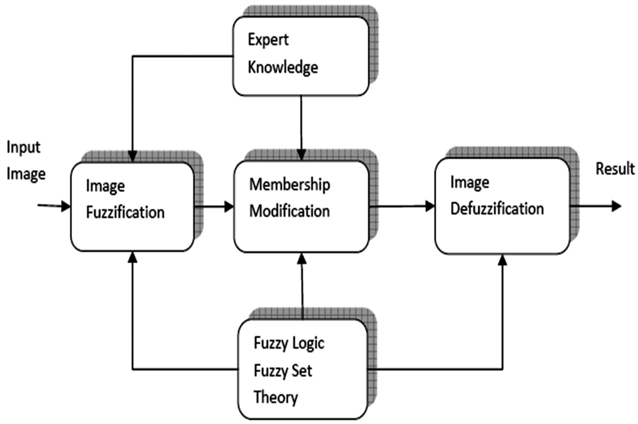

Fig. 1. General structure of fuzzy image processing

2 Existing Method

2.1 Spatial Domain

It is denoted by

$$g(x, y) = T[f(x, y)] \tag{1}$$

Where f(x, y) in the input image, g(x ,y) is the processed image T is the operator on f(x, y). The center of a mark is moved from pixel to pixel from top left corner. The operator T is applied at each location (x, y) to yield g.

2.2 Gray Scale

Here the gray level below the threshold value is mapped to 0 and gray level above threshold value mapped to 255 (Fig. 2).

Original Image Lena Image with Gaussian noise σ =100

Fig. 2. (a) Original image Lena; (b) Image with Gaussian noise σ = 100

2.3 Histogram Equalization

It involves finding a gray scale transformation function that creates an output image with uniform histogram. But here the problem is how to determine the gray scale transformation function. Histogram equalization image Lena is given below (Fig. 3).

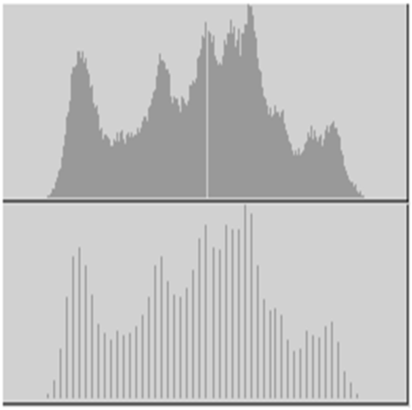

Fig. 3. Histogram equalization of image Lena

2.4 Image Smoothing [4]

Here the technique of neighborhood averaging is employed which results in blurring. We commonly use some weighting function like rectangular weighting function (average) or a triangular weighting function or a Gaussian.

2.5 Averaging

See Fig. 4.

1/9*

1	1	1
1	1	1
1	1	1

Fig. 4. Lena image with Gaussian noise σ = 10 filtered by average filter

2.6 Gaussian Filter

See Fig. 5.

1/16*

1	2	1
2	4	2
1	2	1

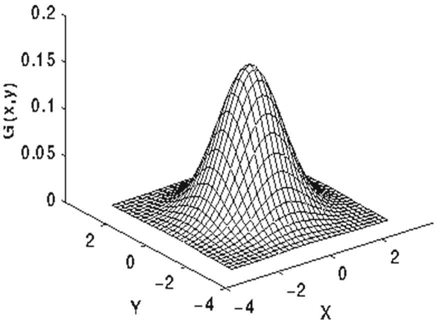

Fig. 5. Gaussian filter

As the above method results in blurring, for edge preserving median filtering is used. Here the pixels with outlaying values are forced to become more like their neighbor. It is a non-liner filter (Fig. 6).

Fig. 6. Lena image with Gaussian noise $\sigma = 10$ filtered by median filter

2.7 Image Sharpening

Here the high frequency components are enhanced as a high positive component is taken at the center. High boost filter can be used when low frequency components are retained along with the high pass image.

2.8 Frequency Domain Methods

Here we enhance the Fourier Transform (FT) of the image. The FT of the image is multiplied by a filter & the inverse transform is taken to enhance the image.

3 Fuzzy Image Enhancement [6–8, 10–12]

It consists of Fuzzification, modification of membership value and Defuzzification. The main power of fuzzy image processing in modification of membership value. First the image data are transformed from gray level plane to the membership plane then appropriate fuzzy technique modify the membership value. This can be a fuzzy clustering a fuzzy rule-based approach and a fuzzy integration approach.

3.1 Generalized Fuzzy Image Enhancement

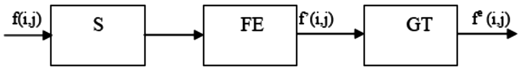

Fig. 7. Block diagram of generalized image enhancement

The smoothing operation S uses median filtering. It is a nonlinear method which suppresses noise and reduces blurring at the same time retains the high frequency components. The fuzzy enhancement method (FE) follows the smoothing operation. The image f*(i, j)* with M *x N* pixels where f_{ij} $i = 1, 2...n$, is the gray level of the pixel. The fuzzy set is represented by $\tilde{F}$ which is explained in the proposed method. μ_{ij} is called the fuzzy property plane. The key to the fuzzy enhancement is a contrast intensification operator is T $\left(\mu_{ij}\right)$ (Fig. 7).

Where,

$$\begin{aligned} \mathrm{T}(\mu_{ij}) &= 2(\mu_{ij})^2, \text{where } 0 \le \mu ij \le 0.5 \\ &= 1 - 2(1 - \mu_{ij})^2, \text{where } 0.5 < \mu_{ij} \le 1. \end{aligned} \tag{2}$$

The image *f(i, j)* can be enhanced in the property domain by a transformation function $T^{(r)}$

$$\mu'_{ij} = T^{(r)}(\mu'_{ij}) = T(T^{(r-1)}(\mu_{ij})), \mathrm{r} = 1, 2\ldots \tag{3}$$

The enhanced image can be obtained by the following inverse transformation

$$f'_{ij} = G^{-1}\left(\mu'_{ij}\right) \tag{4}$$

Where f'_{ij} is the gray level of the *(i, j)th* pixel in the enhanced image and G^{-1} denotes the inverse transformation of G. The final result is obtained by a gray transformation, GT (t) (Fig. 8).

$$f^{e}_{ij} = t(f'_{ij}) = \frac{f^{e}_{max} - f^{e}_{min}}{f'_{max} - f'_{min}}(f'_{ij} - f'_{min}) + f^{e}_{min} \quad (5)$$

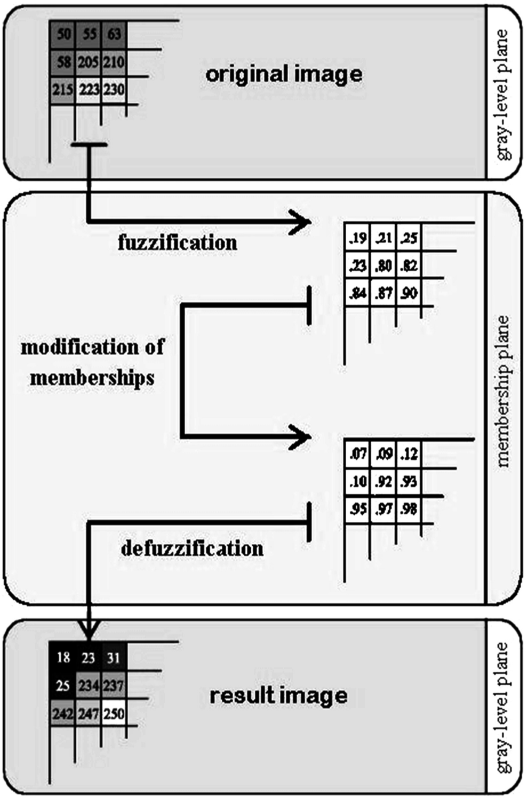

Fig. 8. Fuzzification and defuzzification

4 Proposed Method

As earlier approach proposed method is also divided into three main steps:

(i) Fuzzification
(ii) Iterative computations [9]
(iii) Defuzzification

Given an image f*(i, j)* with M *x N* pixels and f_{ij} levels, and let $f_{ij}\, i = 1,\ 2\ldots n$, be the gray level of the pixel location *(i, j)*. The fuzzy set $\tilde{F}$ corresponding to this image can be written as the following form

$$\tilde{F} = \left(\frac{\mu_{IJ}}{f_{ij}}\right)_{MXN} \tag{6}$$

Where $\left(\frac{\mu_{ij}}{f_{ij}}\right)$, $\left(0 \le \mu_{ij} \le 1\right)$ means the degree of possessing some appointed brightness by the *(i, j)th* pixel with the gray level f_{ij}. This appointed brightness is usually the maximum $f_{\max}$ of gray levels in the image. Here $\mu_{ij} = 0$ indicates dark and $\mu_{ij} = 1$ bright. Any intermediate value refers to the grade of maximum gray level of the pixel. A set consisting of all μ_{ij} is called the fuzzy property plane of the image. In [1] μ_{ij} is expressed as

$$\mu_{IJ} = G(f_{ij}) = \left[1 + \frac{f_{\max} - f_{ij}}{F_d}\right]^{-F_c} \tag{7}$$

Where *Fc* and *Fd* denote the exponential and the denominational fuzzifiers, respectively. It is apparent that those two positive constants have the effect of altering ambiguity in the fuzzy property plane. The key to the fuzzy enhancement is a contrast intensification operator (INT). It is calculated using below equation.

$$\begin{aligned} T(\mu_{ij}) &= \sqrt[2]{\frac{\mu_{ij}}{2}} \quad 0 \le \mu ij \le 0.5 \\ &= 1 - \sqrt[2]{\frac{(\mathrm{i} - \mu \mathrm{ij})}{2}} \\ &0.5 < \mu_{ij} \le 1 \end{aligned} \tag{8}$$

where T is Contrast Intensification Operator (INT). The image *f(i, j)* can be enhanced in the property domain by a transformation function $T^{(r)}$

$$\mu'_{ij} = T^{(r)}(\mu'_{ij}) = T(T^{(r-1)}(\mu_{ij})),\ r = 1, 2\ldots \tag{9}$$

Where $T^{(r)}$ is defined a successive application of T. The enhanced image can be obtained by the following inverse transformation

$$f'_{ij} = G^{-1}\left(\mu'_{ij}\right) \tag{10}$$

Where f'_{ij} is the gray level of the *(i, j)th* pixel in the enhanced image and G^{-1} denotes the inverse transformation of G. The final result is obtained by a gray transformation, GT, of the enhanced image that can be represented as

$$f^e_{ij} = t(f'_{ij}) = \frac{f^e_{max} - f^e_{min}}{f'_{max} - f'_{min}} (f'_{ij} - f'_{min}) + f^e_{min} \tag{11}$$

Where the gray level of the *(i, j)th* pixel, the gray maximum and the gray minimum of the final image are denoted by f^e_{ij}, f^e_{min} and f^e_{max} respectively.

Similarly, f'_{min} and f'_{max} indicate the gray maximum and minimum of the image enhanced by FE, respectively. More ever, the following relationships hold:

$$f'_{min} > f^e_{min} f'_{max} < f^e_{max} \tag{12}$$

5 Proposed Algorithm

The Proposed fuzzy enhancement algorithm is given below.

(i) Input the original image *f(i, j),* let r = 1 and define $f^e_{min}\ and f^e_{max}$.
(ii) For each pixel *(i, j)* replace its gray level by the median of the gray levels in its 3 × 3 neighborhood.
(iii) Calculate the fuzzy property plane μ_{ij} corresponding to the filtered image stated above by Eq. (7).
(iv) Transform the fuzzy property plane stated above by (8) and (9) and the result is denoted by μ'_{ij}.
(v) Solve the inverse transformation (10) of G, and the gray level of thefuzzy-enhanced image can be obtained.
(vi) Calculate the gray transform of the image enhanced by the generalized fuzzy enhancement from (11).
(vii) If the enhancement effect is not satisfying, then let r = r + 1 and go to (iv), otherwise the iteration ends.
(viii) Output the final image.

Parameter selection: Here r is taken as 1,
F_c is 2, and F_d is 250.

6 Simulation and Experimental Results

See Fig. 9.


(a) Original Image Lena (b) Degraded Image

(c)Enhancement using Generalized Fuzzy Image Enhancement

(d) Enhancement using proposed method

Fig. 9. (a) Original image Lena (b) Degraded image (c) A generalized Image Enhancement (d) Enhancement using proposed method

7 Conclusion

Fuzzy system is more suitable for the image enhancement problem where diverse, non-exact, uncertain and inaccurate knowledge of information is available. The generalized image enhancement method using fuzzy set does not work well for images having low gray value and high inaccuracy. The proposed method overcomes the problem and from the simulation analysis it is clear that the result is better than the generalized Fuzzy Image Enhancement.

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