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A COLORED IMAGE DENOISING APPROACH BASED ON FUZZY LOGIC

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ABSTRACT

Digital images are used in various applications in today's life. Digital images are corrupted by various noises. There are many different cases of noises. Image denoising is one of the important tasks in image processing that is being used to improve the quality of a degraded image. The fuzzy-based image denoising has many advantages over the traditional image denoising techniques. It can handle imprecision and ambiguity.

Keywords*:* Image denoising, fuzzy filtering, impulse, fuzzy.

I. INTRODUCTION

The reduction or removal of noise in an image is an essential part of image processing. Noise is any undesired information that contaminates an image. Noise can be introduced in the images during the following processes:

(i) Digital image acquisition process, e.g. For CCD (charged coupled device) camera, electronics signal fluctuations in detector is caused by thermal energy and light levels.

(ii) During image transmission, e.g. Wireless network, which may be corrupted by lightning or other atmospheric disturbance.

II. FUZZY IMAGE DENOISING

Fuzzy image enhancement is based on gray level mapping into a fuzzy plane, using a membership function. The aim is to generate an image of better quality in terms of reduced noise than the original image. Classical filters have very erratic decision making capabilities when compared fuzzy filters. The fuzzy filter employs Fuzzy rules for deciding the gray level of a pixel within a window in the image. Compared to other non-linear techniques, fuzzy filter gives the better performance and is able to represent knowledge in a comprehensible way.

Fuzzy method is able to represent and process human knowledge and applies fuzzy if-then rules. Several fuzzy filters for noise reduction have already been developed. A very important added value of fuzzy set theory is its ability to model and to reason with imprecision and uncertainty. Uncertainty is what occurs when processing an image for noise reduction, because of the fact that one can distinguish degrees of contamination of a pixel in an image. Fuzzy set theory allows to model and to work with this uncertainty. In general, a fuzzy filter for noise reduction uses both numerical information (just as classical filters) and the linguistic information (modeled by fuzzy set theory). This information is processed by fuzzy rules (approximate reasoning), resulting in a (defuzzified) filter output.

III. COLOR IMAGE ENHANCEMENT

The steps that are being followed by the Fuzzy Image Denoising Process are explained with the help of diagram shown in Figure 1.1.

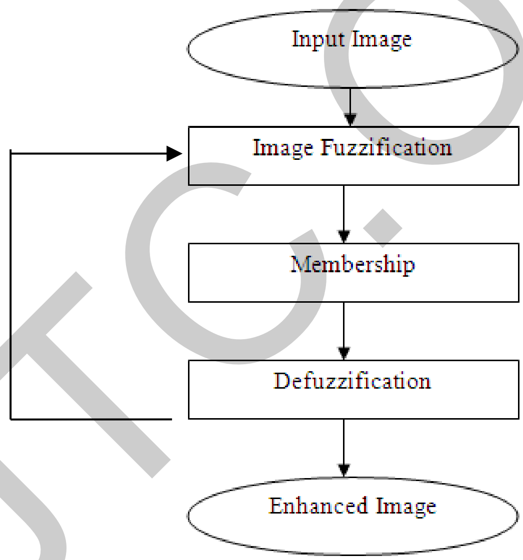

Fig. 1.1: Flow of Fuzzy Image Enhancement Process

The Fuzzy Image Enhancement process consists of four steps:

Image Fuzzification: The fuzzification comprises the process of transforming crisp values into grades of membership for linguistic terms of fuzzy sets. The membership function is used to associate a grade to each pixel. An image *f* of size *M*x*N* and *L* gray levels can be considered as an array of fuzzy singletons, each having a value of membership denoting its degree of brightness relative to some brightness levels. For an image *f*(x,y), we can write in the notation of fuzzy sets as described by Eq. 3.1.

$$f(x,y) = U\ \mu_{xy} / I_{xy} \quad x=1,2,\ldots M \text{ and } y=1,2,\ldots N \quad \ldots(3.1) \quad xy$$

Where I_{xy} is the intensity of (x,y)th value and μ_{xy} is its membership value. The membership function characterizes a suitable property of image like darkness, edginess, textural property etc. and can be defined globally for the whole image or locally for its segments.

Membership: A membership function (MF) is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1. The only condition a membership function must really satisfy is that it must vary between 0 and 1. The input space is sometimes referred to as the *universe of discourse*. A classical set might be expressed by Eq.3.2.

$$A = \{x \mid x > 6\} \qquad \ldots(1.1)$$

A fuzzy set is an extension of a classical set. If X is the universe of discourse and its elements are denoted by *x*, then a fuzzy set A in X is defined as a set of ordered pairs and is described as given by Eq. 3.3.

$$A = \{x, \mu_A(x) \mid x \in X\} \qquad \ldots(1.2)$$

$\mu_A(x)$ is called the membership function (or MF) of *x* in A. The membership function maps each element of X to a membership value between 0 and 1. For finding out the fuzzy membership values, π shaped membership function is used which makes use of the various estimated control parameters. This spline-based curve is so named because of its Π shape. The membership function is evaluated at the points determined by the vector x. The parameters *a* and *d* locate the "feet" of the curve, while *b* and *c* locate its "shoulders." The membership function is a product of smf and zmf membership functions and is described as shown in Eq. 3.4.

$$f(x;a,b,c,d) = \begin{cases} 0, & x \le a \\ 2\left(\frac{x-a}{b-a}\right)^2, & a \le x \le \frac{a+b}{2} \\ 1-2\left(\frac{x-b}{b-a}\right)^2, & \frac{a+b}{2} \le x \le b \\ 1, & b \le x \le c \\ 1-2\left(\frac{x-c}{d-c}\right)^2, & c \le x \le \frac{c+d}{2} \\ 2\left(\frac{x-d}{d-c}\right)^2, & \frac{c+d}{2} \le x \le d \\ 0, & x \ge d \end{cases} \qquad (1.3)$$

Where x is a pixel under consideration and a, b, c and d are control parameters.

Defuzzification: It is the process of producing a quantifiable result in fuzzy logic. Typically, a fuzzy system will have a number of rules that transform a number of variables into a "fuzzy" result, that is, the result is described in terms of membership in fuzzy sets. For example, rules designed to decide how much pressure to apply might result in "Decrease Pressure (15%), Maintain Pressure (34%), and Increase Pressure (72%)". Defuzzification would transform this result into a single number indicating the change in pressure. The simplest but least useful defuzzification method is to choose the set with the highest membership, in this case, "Increase Pressure" since it has a 72% membership, and ignore the others, and convert this 72% to some number.

Iterative computations: The iterative approach is used for the noise reduction in the proposed method. The Experiment of the algorithm is taken with different no. of iterations. Some noisy colored images need fewer no. of iterations while other noisy images may need more no. of iterations to reduce the level of noise. The no. of iterations can be increased till much noise is removed from the images.

III. RESULTS

The proposed filter employs Fuzzy rules for deciding the gray level of a pixel within a window in the image. The proposed algorithm consists of following steps:

Step I: Take the input image (‘bmp’).

Step II: Add Gaussian noise or salt & pepper noise or mixed noise to the original input image.

Step III: Convert the RGB color space to HSV color space by using the specified formulas

Step IV: The values of the neighborhood pixels (n x n window) are stored in array, say v and then sorted in ascending or descending order and let define iteration, itr=1.

Step V: Find out the mean and the median values and store these values in variables, say v_mean and v_median respectively. These median and mean values are used to find the correction term for each pixel in the noisy image.

Step VI: Now, find the range as specified by the Eq. 1.4.

$$v\_range = abs(v\_median - v\_mean); \quad \dots(1.4)$$

Step VII: Assign the fuzzy membership values corresponding to the original pixel values.

This step has following characteristics:

a) A π-shaped membership function is used which is explained in equation 3.4.

b) The control points a, b, c and d are computed using the equations as specified by Eqs. 1.5, 1.6, 1.7 and 1.8. respectively.

$$a = v[1] \quad \dots(1.5)$$

b = v_mean-v_range … (1.6)

c = v_mean+v_range … (1.7)

d = v[7] …(1.8)

Step VIII: Find out the maximum membership value and assign the highest membership value to the central pixel.

Step IX: Convert HSV color space back to the RGB space using the specified formulas.

Step X: If the enhancement effect is not satisfying, then let itr=itr+1 and go to Step III, otherwise the iteration ends. In this way, no. of iterations can be increased till the noise is removed to satisfactory level.

Step XI: Output the Final image.

The proposed method shows better output both qualitatively and quantitatively. As the proposed technique is developed using MATLAB and Visual C++, its result features are explained below.

Input image is “blackbuck.bmp” as shown in Fig. 1.2.

Fig. 1.2: Original Blackbuck.bmp

Now, to add noise in the images, on MATLAB prompt, type functions as described by Eqs. 1.9 and 1.10.

```
>> I = imread('blackbuck.bmp');                 …(1.9)
>> J=imnoise(I , 'salt & pepper',0.10);         …(1.10)
```

The noisy image is described as shown in Fig. 1.3.

Fig. 1.3: Blackbuck.bmp corrupted by ‘salt & pepper’ noise

Save this image to the directory of Visual C++. This noisy image becomes the input of the proposed filter.

Now, Run the Visual C++ file of the proposed algorithm. The following output window is displayed as shown in Fig. 1.3. The filtered image is saved in the Visual C++ directory.

The filtered image is shown as shown in Fig. 1.4

Fig. 1.4: Filtered blackbuck.bmp

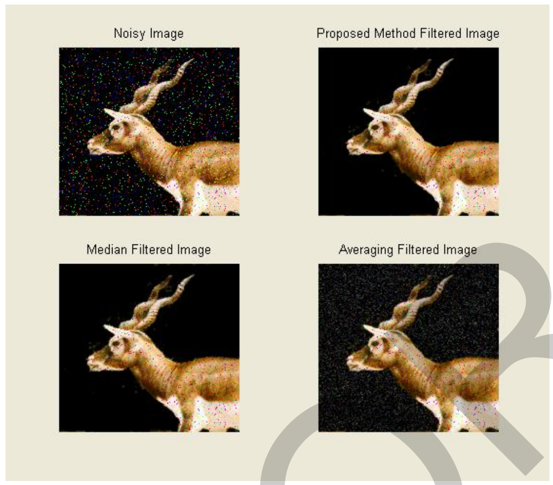

Fig. 1.5: Noisy image 'blackbuck.bmp' corrupted by 'salt & pepper noise' and Output images with different filtering schemes (using a 3X3 mask).

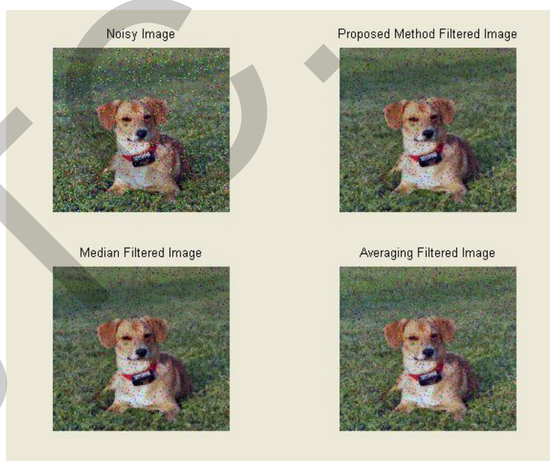

Fig 1.6: Noisy image 'pet.bmp' corrupted by 'salt & pepper noise' and Output images with different filtering schemes (using a 3X3 mask).

Density of Noise	Metrics	Methods			
		Noisy Image	Averaging Filter	Median Filter	Proposed Method

Blackbuck.bmp					
5%	MSE	36.65	22.30	9.93	**9.00**
	PSNR	16.84	21.16	28.18	**29.11**
10%	MSE	52.09	35.50	14.57	**13.20**
	PSNR	13.79	17.12	24.85	**26.22**
15%	MSE	63.82	46.92	18.99	**18.01**
	PSNR	12.03	14.70	22.55	**23.53**
Pet.bmp					
5%	MSE	27.69	15.19	8.50	**8.04**
	PSNR	19.28	24.49	29.54	**30.01**
10%	MSE	39.44	23.33	11.53	**10.28**
	PSNR	16.21	20.77	26.88	**27.88**
15%	MSE	48.09	30.60	14.40	**12.28**
	PSNR	14.48	18.41	24.96	**26.34**

IV. CONCLUSION

Image enhancement is used to improve the quality of an image for visual perception of human beings. The main techniques for image enhancement are contrast stretching, slicing, histogram equalization etc. for gray-scale images. The generalization of these techniques to color images is not straight forward. Unlike gray scale images, there are some factors in color images like hue which need to be properly taken care of for enhancement.The fuzzy rule-based approach is a powerful method for formulation of expert system in a comprehensive way. From the various observations, it is clear that the fuzzy techniques for image noise reduction indeed have an added value in the field of image enhancement.

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