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Eliminate Noise with Fuzzy Logic Based on the (PSO) Algorithm

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Abstract - **This paper presents a fuzzy logic based filter with the capability of removing pepper-and-salt noise and smoothing Gaussian noise to keep edges and details of image simultaneously and effectively. In order to gain these three purposes for image enhancement, we first expand filters that have strong abiliity of keeping the details of edges and do not perform well in Guassian noise smoothing. Then we change the filters in a way that they would be able to perform these three enhancement operations on images. These filters are based on the idea that single pixels should not be excited (fired) uniformly by each of fuzzy rules. In order to demonstrate the capabilities of this filtering method, we tested it on different problems of image enhancement. Experimental results show the speed, quality and the accuracy of new filtered images.**

Keywords: Fuzzy Logic – Image Processing - particale swarm optimization- edge enhancing

I. INTRODUCTION

Noise smoothing and upgrading the images are inconsistent aims in most image processing applications. Image enhancement objectives include: eliminating the pepper-and-salt noise, improving the main colors, upgrading the edges and other prominent structures of input image. The noise filtering refers to replacement of the grey level of each pixel in the image with new value which is dependent on the local background of those images. Ideally, the filtering algorithm has to change from pixel to pixel based on the local background. For instance, if the local area is relatively smooth the new value of pixel, can be determined by averaging the values of neighborhood pixels. On the other hand, if the local region contains the pixels of the edge and pepper-and-salt noise, a different kind of filtering must be used. Although this operation is complicated but it's not impossible. Therefore, the local area can only vaguely, in some parts of the image, be evaluated. Therefore, we need a filtering system which is able to infer ambiguous and unreliable information using fuzzy logic.[1,3]

Noise smoothing and upgrading the images in one area are intuitively inconsistent. In this paper we propose a new filter based on fuzzy logic control that eliminates the pepper-and-salt noise. Furthermore, it performs noise smoothing so that edges and details of the image are effectively kept. This filter is based on the idea that single pixels do not get excited uniformly by each of fuzzy rules.[4,5,7,8]

The rest of this paper is organized as follows. In section 2 we propose our method and show its main properties. Section 3 demonstrates experimental results. Section 4 we apply some changes to improve the efficiency of the proposed filter.

II. THE PROPOSED METHOD

This part presents the structure of our proposed fuzzy control filter (FCF). In FCF system, we employ the general structure of the mechanism of fuzzy *if-else-then* rule in a way that does not allow each point in the desired space to be excited uniformly by the basic fuzzy rules. As we explain later, inconsistency in image decreases the sensitivity of pepper-and-salt and provides improvement in the recovery of the edge.

In order to filter the image, the following fuzzy rule and membership function, in figure1, is proposed.[4]

R1: IF(more of x_i are NB) THEN y is NB (1)

R2: IF(more of x_i are NM) THEN y is NM

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R3: IF(more of x_i are NS) THEN y is NS

R4: IF(more of x_i are PS) THEN y is PS

R5: IF(more of x_i are PM) THEN y is PM

R6: IF(more of x_i are PB) THEN y is PB

R0: ELSE y is Z

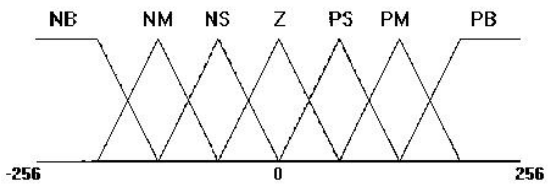

Figure 1. Membership functions

Above part, shows that x_i is the illumination differences between neighboring pixels. P_i (located in a window with N×N size) and P is the central pixel. The proposed algorithm in this method is the movements of birds.[18]

Here, in order to create similar neighbors, we pick up the best neighbors. The pattern of selecting the best neighbor is that we select the nearest N*N neighbor to the central pixel. The output variable y is a quantity which is added to P in order to calculate the level of illumination of the result pixel P’. The word *more* represents the fuzzy function that its typical form is shown in figure 2. The form of this function activates the inconsistent excitation of the basic fuzzy rules.

The type of the function S can be described with the following formula:

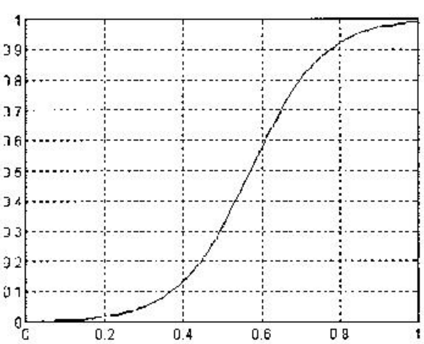

Figure 2.The Membership functions for the Fuzzy function “more”

A. Calculation of the Degree of Activity of the Rules

The degree of the activity of R1 is calculated with the following relation (degree of the activity of the subsequent *if-then* rules are measured similarly).

$$\lambda_1 = \min\{\mu NB(xi) : xi \in \text{support}(NB)\} \times \mu more \times \left[\frac{\text{number of xi which xi} \in \text{support (NB)}}{\text{total number of xi}}\right]. \quad (2)$$

We use the following formula to calculate the degree of activity of the rule ELSE or R0.

$$\lambda_1 = \text{Max}\{0, 1 - \sum_{i=1}^{6} \lambda_i\} \quad (3)$$

In order to calculate the numeral output from the fuzzy rules given in (1), we use the mechanism of multiplied correlation:

$$y = \frac{\sum_{i=0}^{6} ciwi\lambda i\}}{\sum_{i=0}^{6} wi\lambda i\}} \quad (4)$$

That C_i and w_i are respectively the central point and the width of the membership function used in the fuzzy rule Ri, in (1). Considering the point that all $w_i$are equal and C_0=0, the relation (4) can be simplified as follows:

$$y = \sum_{i=1}^{6} ci\lambda i \quad (5)$$

B. Bird Movements of the Program

Particles move in a multi-dimensional search space, in which the position of each particle is adjusted by the knowledge of the particle itself and the knowledge of it neighbors. If x_i (t) represents the position of the i particle in the search space of the time t, the position of the i particle is calculated by the total speed of that particle (v_i (t)), with respect to its current position, according to the following relation:

$$x_i(t+1) = x_i(t) + v_i(t+1) \quad (6)$$

Which at first, the amounts of the initial position will be selected by the relation of $x_i(0) \sim U(x_{i_{min}}, x_{i_{max}})$.

C. Model of Optimization of the Community of Overall Particles

$$v_{ij}(t+1) = v_{ij}(t) + c_1 r_{1j}(t) \quad (7)$$

$$[y_{ij}(t) - x_{ij}(t)] + c_2 r_{2j}(t)[\hat{y}_j(t) - x_{ij}(t)].$$

Here, $v_{ij}(t)$ is the speed of particle i in the dimension of j=1,…,$n_x$and in the time t, x_{ij}(t) is the position of particle i in dimension j and in time t. $c_1$and $c_2$are factors of the increase of speed that are respectively for the measurement of the shares of perceptive and social components. There is also r_{1j}(t) , r_{2j}(t)

~ U(0,1)which is calculated randomly and with uniform distribution. These random amounts (values) represent the random components of this algorithm. Position y_i related to i particle is the best position observed by the particle from the beginning of the process. For minimization, the best position, in the time t+1, is calculated as follows:

$$y_i(t+1) = \begin{cases} y_i(t) & f(x_i(t+1)) \geq f(y_i(t)) \\ x_i(t+1) & f(x_i(t+1)) < f(y_i(t)) \end{cases} \quad (8)$$

D. Main Features

As it is observed in relation (2), the filter obtained from achieved rules of relation (1), has the following advantages due to their uniform activities:

(1) Sensitivity to the Low Noise: rate of the signal sensitive to noise, for pixels that are positioned in a categorized space, symmetric rules related to noisy pixels are excited for fewer number of times. Therefore, their contribution in filter decreases.

(2) Keeping the Edge: in areas at the proximity of the bounderies, the output is calculated by the area that has the more pixels. Therefore, the edges of the image will not be faded.

III – EXPERIMENTAL RESULTS

As mentioned above, FCF has the potential to keep the edges. To approve this feature, we need to, evaluate the filtering quality, quantitatively. We employ the mean-square-error (MSE) as the criterion for the capability of keeping the edges, between the edges of the main image and the image after filtering. We use the term MSEE to show this criterion. Hence, we do a number of experiments to demonstrate the function of FCF.

Experiment1- Keeping the Edge

The image presented in figure 3 is the first sample for FCF. MSEE is the filtered images obtained from FCF, Median Filter, and other Filters, according to chart1, are summarized (image filters are extracted with the Sobel operator). Notice that FCF (with one frequency) had a better edge keeping in comparison with other filters.

Figure 3. The test Image, Complex

Figure 4. The test Image two

Table 1. Comparison of filter types and edge preserving criteria MSEE

Filter Type	MSEE
Median 3*3	**610**
Median 5*5	**1682**
FWM	**506**
EPS 5*5	**847**
EPS 7*7	**1053**
ENHANCE 3*3	**577**
ENHANCE 5*5	**1102**
FCF 3*3 (after 1iteration)	**76**
FCF 3*3 (after 4 iteration)	**359**

Experiment2- Impulsive Noise

In this experiment we analyze figure 5(a), so that the test image is combined with the impulsive noise of 5% white and 5% black. The FCF result after 4 iterations is shown in figure 5(b). According to this retrieved image, we can say that FCF can eliminate the noise from the image without eliminating the edge.

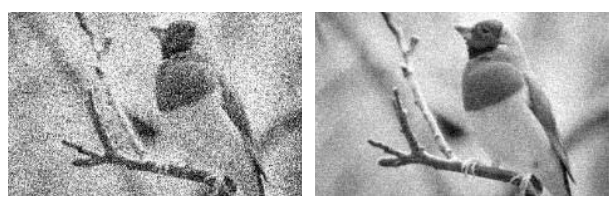

Figure 5 (a) 320 × 200 test image with 256 gray levels, combined with 10% impulsive noise, (b) result after 4 iterations of FCF.

Experiment3- Gaussian and Mixed Noise

In order to demonstrate the function of this filter in a Gaussian Noise environment, we analyze the image Lena as another sample. This image was initially mixed with Gaussian Noise with $\mu=0$ and $\sigma^2=400$ and then was employed on our filter. Results of the filtering are shown in figure 6(a). In this figure we see that by increasing the number of frequency, MSE will be decreased. In order to test the function of FCF in the mixed noise, we apply the impulsive noise (2.5%, 2.5%) to the previous image. The result is shown in figure 6(b). For both cases of Gaussian and Mixed noises, FCF improves the image by increasing the frequency. Yet we show in the next experiment that we cannot increase the number of frequency infinitely.

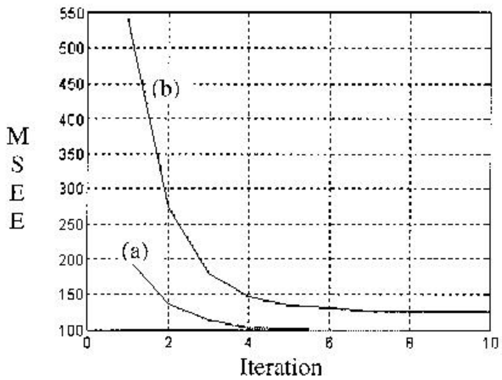

Figure 6. FCF performance on the image Lena in size 256×256 combined with Gaussian noise (a) without Gaussian noise (b) with impulsive noise (2.5%,2.5%).

Experiment4- Effects of the Frequency on Keeping the Edge

In this experiment we use the image Lend. Figure7, MSEE shows a recovered image that is obtained by FCF as a function of the iteration. This image shows that the edges are failed by increasing the iteration. According to figure 6 and 7, it can be seen that there is some sort of consistency between keeping the edge and recovery of the noisy image. In the next experiment we limit the number of iterations to 4.

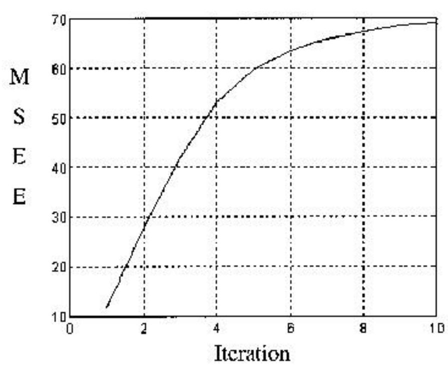

Figure 7. FCF efficiency decrease on the image Lena

Experiment5- Complex Image in Noise

In order to emphasize again the performance of FCF in a noisy environment, we analyze the image in figure8. This image is extracted from image3 that is mixed with Gaussian noise (μ=0 and σ^2=400) and the impulsive noise (2.5%, 2.5%).

Figure8.noise in figure3.

Figures 9-12 show the operation of different filters on the image of figure8.

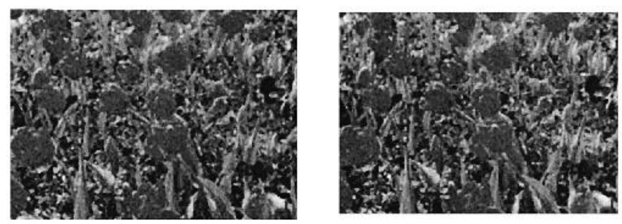

Figure 9 - Image retrieval with (a) 3 × 3 median filter and (b) FWM filter

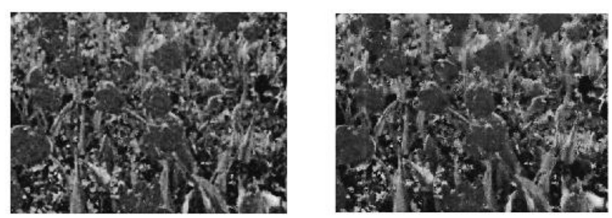

Figure 10 - (a) 5 × 5 EPS filter and (b) 7 × 7 EPS filter

Figure 11 - (a) 3 × 3 ENHANCE filter and (b) 5 × 5 ENHANCE filter

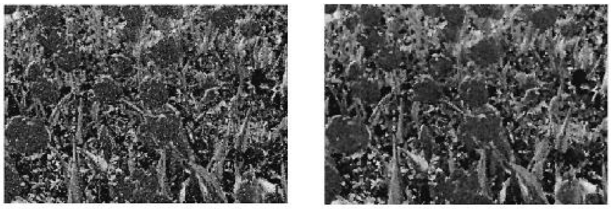

Figure 12 - (a) FCF after one iteration and (b) FCF after four iterations.

IV. CONCLUSION

In this paper, a new method of FCF, including the Fuzzy Control Filter is presented to determine the amounts of neighboring pixels in one image by the movements of the birds, in a way that it finds the best position of each pixel in the image and after applying the fuzzy function, eliminates the pepper-and-salt noises of the image. This method has high accuracy in image recovery, keeping the details of the image and edges, and enhance of the main colors of the image effectively and accurately. This method is more accurate than the linear difference method.

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