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A New Method of Image Denoising Based on Fuzzy Logic

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Abstract: Nonlinear techniques have recently assumed significance as they are able to suppress Gaussian noise which is also called as white additive noise to preserve important signal elements such as edges and fine details and eliminate degradations occurring during signal formation or transmission through nonlinear channels. Among nonlinear techniques, the fuzzy logic based approaches are important as they are capable of reasoning with vague and uncertain information. This study presents a new fuzzy filter for suppressing noise in lena image and satellite image to show the feasibility of the proposed noise reduction using Fuzzy filter approach and compare it with the existing Mean, Median Filter and Non-Local means Algorithm. This filtering method is more efficient to remove the noise for low noise levels.

Key words: Gaussian noise, fuzzy logic, image processing, membership function

INTRODUCTION

Noise Reduction in images is an essential part in image processing the most common type of noise in image is Gaussian noise. Noise can be generated during image capture, transmission, storage, copying, scanning and display. Gaussian noise can be expressed in terms of its mean and variance values. Gaussian noise can be generated during film exposure and development. Several filtering techniques have been proposed over the years. The filtering involves the removal or reduction of the Gaussian noise or while additive noise while preserving or enhancing edges. The edges give the image the appearance depth and sharpness. A loss of edges makes the image appear blurred or unfocused.

A better solution to a seemingly blind approach to noise reduction is to process the image by its individual pixels based upon the trends or appearance of its immediate neighbors. These trends can be defined as statistical characteristics of the neighboring pixels or they can be based on the fuzzy classification of the each pixels. Fuzzy technique have been applied in several domains of image processing (Menhardt, 1988). A major problem of many image processing techniques is that they cannot work well in a noisy environment. Digital images are valuable and important sources of information for a variety of research and application area. In this study, we will focus on fuzzy techniques for digital image filtering. More specifically we will concentrate on a fuzzy logic approach for the enhancement of the image corrupted with Gaussian noise. The main goal of Gaussian noise reduction method is to suppress the noise while preserving the fine details and edge elements. Non linear techniques have been found to provide more satisfactory results in comparison to linear method.

A number of non linear approaches have been already developed for Gaussian noise removal, for example the well known Non Local means algorithm (NL). These filter (Baudes *et al*., 2005) does not make the same assumptions about the image as other methods. Instead it assumes the image contains an extensive amount of self similarity. The mean filter (Lee *et al*., 1997) and median filter (Arakawa, 1996) are other examples of the state-of-the-art methods. The goal of this study is to develop a Gaussian noise reduction method.

NOISE

Noise is any undesired information that contaminates an image. Noise is the result of errors in the image acquisition process that result in pixel values that do not reflect the true intensities of the real scene. Noise in images can be the result of small discrepancies in the hardware we use to digitize our analog world, such as thermal excitation of CCD sensors during long exposures, or simply dirt and scratches on the lenses. The characteristics of noise depend on their sources.

In this study we are going to deal with gray scale image. Gray color in gray scale image is one which has the equal intensity in RGB space. So it is enough if we specify one intensity value for each pixel. Gray scale intensity is stored in 8-bit integer giving 256 possible different shades going from black to white.

NON-LOCAL MEANS METHOD

This was adopted in (Baudes, 2004). Each pixel p of the non-local means denoised image is computed with the following formula:

$$NL(V)(P) = \sum_{q \in V} w(p,q)\, V(q)$$

Where, V is the noisy image and weights w(p,q) meet the following conditions and $0 \leq w(p,q) \leq 1$ and $\Sigma_q (p,q) = 1$. Each pixel is a weighted average of all the pixels in the image. The weights are based on the similarity between the neighborhoods of pixels p and q (Alvarez *et al.*, 1992). The weight w(p,q1) is much greater than w(p,q2) because pixels p and q1 have similar neighborhoods and pixels p and q2 do not have similar neighborhoods. In order to compute the similarity, a neighborhood must be defined. Let N_i be the square neighborhood centered about pixel i with a user-defined radius Rsim. To compute the similarity between two neighborhoods take the weighted sum of squares difference between the two neighborhoods or as a formula

$$d(p,d) = \| V(N_p) - (N_q) \|_2^2\, F$$

F is the neighborhood filter applied to the squared difference of the neighborhoods. The weights can then be computed using the following formula:

$$w(p,q) = \frac{1}{Z(P)} e^{\frac{-d(p,q)}{h}}$$

Z(p) is the normalizing constant defined as (Lee *et al.*, 1997)

$$Z(p) = \sum_q e^{\frac{-d(p,q)}{h}}$$

Where, h is the weight-decay control parameter.

As previously mentioned, F is the neighborhood filter with radius Rsim. The weights of F are computed by the following formula:

$$\frac{1}{Rsim} \sum_{i=m}^{Rism} 1/(2*i+1)^2$$

Where, m is the distance the weight is from the center of the filter. The filter gives more weight to pixels near the center of the neighborhood and less weight to pixels near the edge of the neighborhood. The center weight of F has the same weight as the pixels with a distance of one (Baudes *et al.*, 2005).

MATERIALS AND METHODS

Fuzzy filter uses the concept of fuzzy logic. The general idea behind the filter is to average a pixel using other pixel values from its neighborhood, but simultaneously to take care of important image structures such as edges using block size. Such a value is derived for each direction corresponding to the neighboring pixels of the processed pixel by a fuzzy rule.

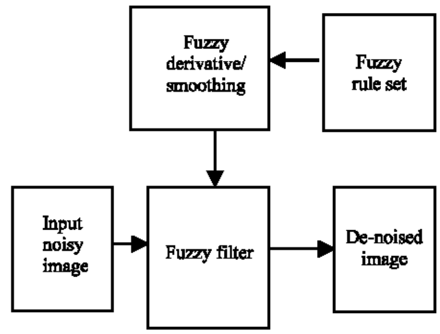

Fig. 1: Analysis on image denoising using fuzzy logic algorithm

The further construction of the filter is then based on the observation that a small fuzzy derivative most likely is caused by noise, while a large fuzzy derivative most likely is caused by an edge in the image. Fuzzy derivative is defined as the difference between the pixel at (x,y) and its neighbor in the direction.

NW	N	NE
W	(x,y)	E
SW	S	SE

The above Fig denotes neighborhood of a central pixel (x,y).

	NW	N	NE
	W	(x,y)	E
	SW	S	SE

Pixel values indicated in gray are used to compute the fuzzy derivative of the central pixel (x,y) for the NW-direction. Membership function is calculated which is nothing but finding the positive, negative value of the pixel. The maximum grey value is found out and it is subtracted with other pixel. The maximum grey value pixel is considered to be positive and other pixel is considered to be negative.

Next is Fuzzy smoothing which converts negative pixel to positive pixel. This is done for all the other pixel. This provides clarity of image without destroying the quality of the image.

Nonlinear fuzzy filter found most effective in reducing white additive noise. Figure 1 shows the proposed filtering technique based on Fuzzy rule set.

- Let V be a noisy image V= { v(i)/ iΣ I}
- Detection of noisy pixels using NL means

- The membership degree of fuzzy set μ(v(i,j) and D as the output image
- If v(i,j) Σ I

$$D(i,j) = \frac{\sum_{p=m}^{n}\sum_{q=m}^{n} 1 - \mu(v(i+p, j+q)}{\sum_{p=m}^{n}\sum_{q=m}^{n} 1 - \mu(i+p, j+q)}$$

RESULTS AND DISCUSSION

The proposed filter is applied to 8 bit satellite image Lena and image of dimensions 256×256 pixels, after adding Gaussian noise of different levels. The square windows of dimensions N X N pixels of width N = 3 is used. This procedure is allowed us to compare and evaluate the filtered image against the original one. Figure 2 shows the representative test images for added noise σ = 20 : Lena.

Figure 3 is the original satellite image of a part of Greece and tested in terms of visual quality. This image contains white additive noise. since the original image contains the noise it must be removed by using filters.

The Mean Square Error (MSE) is used to compare the relative filtering performance of various filters. Top evaluate the results, we computed the MSE between the filtered output image P(i,j) and the original image q(I,j) of dimensions R1XR2pixels is defined as:

$$MSE = \frac{\sum_{i}^{R1}\sum_{j}^{R2} [q(I,j) - p(I,j)]^2}{R1 \times R2}$$

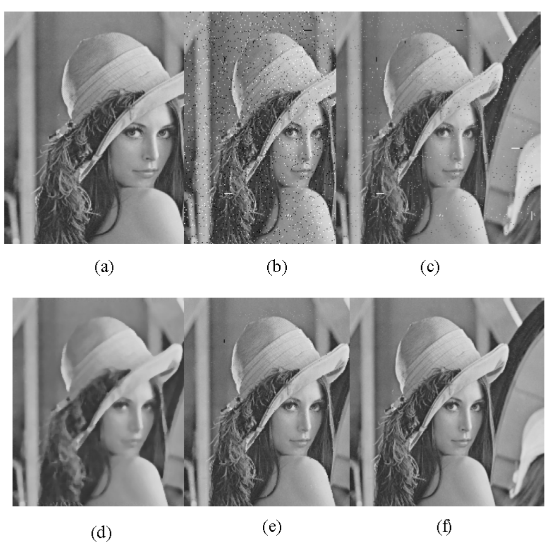

Fig. 2: Comparison of Gaussian noise removal performance: (a) Original Image, (b) Corrupted Image with 20% mixed Gaussian noise, (c) Restored using 3×3 Mean, (d) Restored using 3×3 Median, (e) Restored using NL method and (f) Restored using fuzzy filter

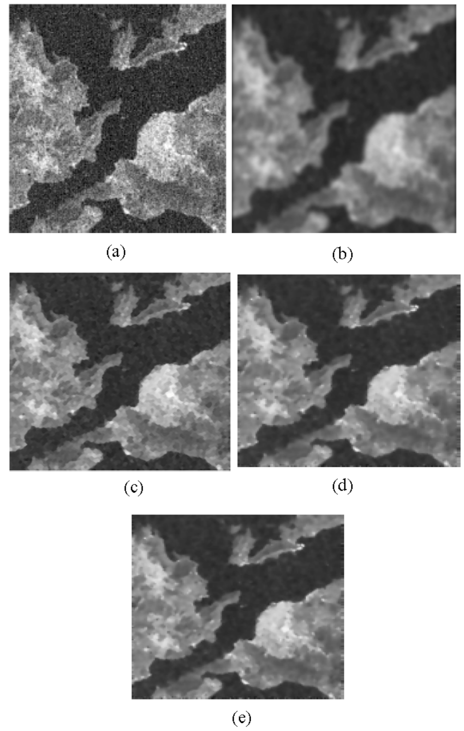

Fig. 3: Comparison of Gaussian noise removal performance: (a) Corrupted Image,,(b) Restored using 3×3 Mean, (c) Restored using 3×3 Median, (d) Restored using NL method and (e) Restored using fuzzy filter

Table 1: Comparison of the MSEs of restored images

Filter	MSE
Mean filter (3×3)	382
Median Filter (3×3)	244
NL-mean method	126
Proposed filter	112

The MSE of the original and filtered noisy Lena image of Gaussian noise for N = 3 is summarized in Table 1. From the filtered images, it is observed that edges and details are preserved for N = 3 in the proposed filter.

CONCLUSION

This study proposed a new fuzzy filter and their filtering performance for additive noise reduction has been presented. Fuzzy rules are used to compute the value of the center pixel by applying a weighted membership function to an image within a window and consider every direction around the processed pixel. It is easy and fast to implement and can suppress Gaussian noise with a varying degree of success. A numerical measure, such as MSE and visual observation for Lena and Satellite image show convincing results. The proposed filter performed marginally better than the existing method.

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