Fuzzy Logic based Soft Filters for Removing Noise and Preserving Edge

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***Abstract* - The image corrupted by different kinds of noises is a frequently encountered problem in image acquisition and transmission. The noise come from noisy sensors or channel transmission errors. Several kinds of noises are discussed in literatures. The impulse noise (or salt and pepper noise) is caused by sharp, unexpected disturbances in the image signal; its appearance is randomly scattered white or black (or both) pixels over the image. Gaussian noise is an idealized form of white noise, it is caused by random fluctuations in the signal. Speckle noise (or more simply just speckle) can be modeled by random values multiplied by pixel values; hence it is also called multiplicative noise. This paper presents a detailed survey of various impulse noise reduction techniques. The techniques are all based classical filters and on Fuzzy logic. Different types of noises and their causes are discussed first and then various fuzzy filters are discussed about. The Fuzzy techniques are studied and their performance is analyzed based on various image quality assessment parameters.**

***Keywords* - Image denoising, Salt & pepper noise, PSNR (Peak Signal to Noise Ratio), fuzzy switching median.**

I. INTRODUCTION

The fundamental problem of image and signal processing is to effectively reduce noise from a digital image while keeping its features intact (e.g., edges). Three main types of noise exist: additive noise, impulse noise, and multiplicative noise. Impulse noise is usually characterized by some portion of image pixels that are corrupted, leaving the remaining pixels unchanged. Examples of impulse noise are fixed-valued impulse noise and randomly valued impulse noise. The additive noise comes when a value from a certain distribution is added to each image pixel, for example, a Gaussian distribution. Multiplicative noise is generally more difficult to remove from images than additive noise because the intensity of the noise varies with the signal intensity (e.g., speckle noise). A grayscale digital image A is represented by a two dimensional array where an address (x, y) defines a position in A called a picture element or a pixel. The grayscale intensity is stored as an 8-bit integer giving 256 possible shades of grey going from black to white. It may be represented as [0, 255] integer interval. In this interval, we consider numerous integer values p1, p2, p3… pn. If A(x, y) denotes the value of the image A at position (x, y), then the occurrence of impulse noise can be modeled as [3]:

= A(x, y) with probability 1-pr

= p1 with probability pr_1

N(x, y) = p2 with probability pr_2

= pn with probability pr_n

II. FILTERS

A. Linear filter

Linear filter used to remove certain types of noise. Averaging or Gaussian filters are appropriate for this purpose. Linear filters also tend to vague impression sharp edges; destroy lines and other fine image details. Some Filters are discussed in bellow.

1) Mean Filter

In case of mean filter, the value of the central pixel is replaced by the mean value of the pixels that constitute the window. Mean filters are unable to remove impulse noise but reduces Gaussian noise up to certain levels of noise. A mean filter acts on an image by smoothing it; i.e., it reduces the intensity variation between adjacent pixels. The mean filter is a simple sliding window spatial filter that replaces the center value in the window with the average of all the neighboring pixel values including it. By doing this, it replace pixels, that are unrepresentative of their surroundings [8]. It is implemented with a convolution mask, which provides a result that is a weighted sum of the values of a pixel and its neighbors. The mask or kernel is a square. Often a 3x3 square kernel is use. If the coefficients of the mask sum up to one, then the average brightness of the image is not changed [13]. If the coefficients sum to zero, the average brightness is lost, and it returns a vague images. The mean filter is a simple sliding-window spatial filter that replaces the center value in the window with the average (mean) of all the pixel values in the window.

2) Adaptive Filter

An adaptive filter is a filter that self-adjusts its transfer function according to an optimization algorithm driven by an error signal. Adaptive filters are required for some applications because some parameters of the desired processing operation are not known in advance. The adaptive filter use feedback in the form of an error signal to refine its transfer function to match the changing parameters.

An adaptive filter does a better job of denoising images compared to the averaging filter. The fundamental difference between the adaptive filter and the mean filter lies in the fact that the weight matrix varies after iteration in the adaptive filter while it remains constant throughout the iterations in the mean filter. Adaptive filters are capable of denoising non-stationary images, it is, images that have abrupt changes in intensity. Such type of filters is known for their ability in automatically tracking an unknown circumstance or when a signal is variable with little a priori knowledge about the signal to be processed. In general, an adaptive filter iteratively adjusts its parameters during scanning the image to match the image generating mechanism. This mechanism is more significant in practical images, which tend to be non-stationary. Compared to other adaptive filters, the Least Mean Square (LMS) adaptive filter is known for its simplicity in computation and implementation. The fundamental model is a linear combination of a stationary low-pass image and a non-stationary high-pass component through a weighting function. Thus, the function provides a compromise between resolution of genuine features and suppression of noise.

B. Non Linear Filter

Nonlinear filters have quite different behavior compared to linear filters. For non-linear filter, the filter or the filter output response in particular adhere to the principles outlined earlier does not change the scaling and invariance. Moreover, a nonlinear filter can produce results that vary in a non-intuitive manner.

1) Median Filter

The simplest nonlinear filter to consider is the median or rank-order filter. In the median filter, filter output mostly depends on the ordering of input values, usually ranked from largest to smallest or vice versa. A filter support range with an odd number of values is used, making it easy to select the output. The median filter is normally used to reduce noise in an images, somewhat like the mean filter. However, it is often useful in image filter works better means of preserving detail. The median filter is also a sliding-window spatial filter, but it replace the center value in the window with the median of all the pixel values in the window. The mean filter, the kernel is usually square, but can be any size. Working of Median Filter is same as Average filter but here central pixel value is replace by the median value of its neighboring pixels that comes within the window. Median filtering is very effective in reducing the low levels of impulse noise.

C. Fuzzy Filter

Fuzzy filters provide promising result in image-processing tasks that cope with some drawbacks of classical filters [5]. Fuzzy filter is capable of dealing with vague and uncertain information [5]. Sometimes, it is required to recover a heavily noise corrupted image where a lot of uncertainties are present and in this case fuzzy set theory is very useful. Each pixel in the image is represented by a membership function and different types of fuzzy rules that considers the neighborhood. Information or other information to eliminate filter removes the noise with blurry edges but fuzzy filters perform both the edge preservation and smoothing. Fuzzy set theory and fuzzy logic [1] offer us powerful tools to represent and process human knowledge represented as fuzzy rules. Fuzzy image processing [2] has three main stages:

1) Image Fuzzyfication,
2) Modification of membership values,
3) Image Defuzzyfication

Figure 1. Input to mean filter corrupted with salt and pepper noise

Therefore, the coding of image data (Fuzzyfication) and decoding of the results (Defuzzyfication) are steps that make it possible to process images with fuzzy techniques. The important and main power of fuzzy image processing lies in the second step (modification of membership values)[12]. After the image data is transformed from a input plane to the membership plane (fuzzyfication), suitable fuzzy techniques modify the membership values [11][12]. It can be a fuzzy clustering, a fuzzy rule-based approach, and a fuzzy integration approach etc.

III. THE WORK HAS ALREADY BEEN DONE IN THE FOLLOWING FILTERS

A Mean Filter

Fig.1 is the one corrupted with salt and pepper noise with a variance of 0.05.The output image after fig.1 is subjected to mean filtering is shown in fig.2. It can be observed from the output that the noise dominating in Fig.1 is reduced in fig.2. The white and dark pixel values of the noise are changed to be closer to the pixel values of the surrounding ones. Also, the intensity of the input image remains unchanged because of the use of the mask, which amounts to a coefficient value. Means noise filter must be removed in some areas of the image, which is used in applications. In other words, the mean filter is useful when only a part of the image needs to be processed.

Figure 2. Image after mean filtering

B Median Filter

A median filter belongs to the class of nonlinear filters unlike the mean filter. The median filter also follows the moving window principle similar to the mean filter. The input image and the size of the window are the parameters the function takes. Fig. 3 is the image corrupted with salt and pepper noise and we apply median filtering. The window specified is of size 3×3. Fig.4 is the output after median filtering.

Figure 3. Input to median filter

Figure. 4 Output from median filter

C Summary for Both Method

PSNR values for filtering approach

S. No.	Method	PSNR Value
1	Mean filter	27.43
2	Median filter	33.3139

IV. IN THE FOLLOWING SECTIONS, SOME OF THE RECENT FUZZY FILTERS ARE DISCUSSED AND ANALYZED

A Fuzzy Logic & Median Heuristic Filter

This filter was used to detect & remove impulse noise in grayscale digital images. Developed method worked in two steps, in first step noisy pixels were detected using fuzzy reasoning with lowest uncertainty, and in second step noisy pixels were replaced with a heuristic median filter[10].The method was analyzed with PSNR (Peak Signal-to-Noise Ratio) metric and visual comparison. This method is very good for noise reduction and image restoration in high level noisy images**.**

B Noise Adaptive Fuzzy Switching Median Filter

Modifications to Fuzzy switching median filter were made by Kenny Kal Vin Toh etal in a new filter named Noise-adaptive fuzzy switching median filter. The NAFSM filter [12] works on the same principle of Fuzzy switching median filter in the fact that both use the noise histogram to detect the noisy pixels from the original image. The basic and more advanced feature of NAFSM is that it adapts itself according to the amount of noise present in the image. While in fuzzy switching median filter, it used the fixed sized window i.e. 3 x 3 window to process the central pixel, in case of NAFSM, it used initially 3x3 window and increases the window size automatically according to the high levels of noise present. The filter works in the usual two steps viz. the noise detection stage and the noise filtering stage. In detection stage the filter uses the histogram of the noisy image to detect the noisy pixels.

C Fuzzy Logic Technique in Digital Images using Edge Detection

In this paper, effective fuzzy logic based edge detection has been presented [7]. This technique uses the edge strength information derived using three masks to avoid detection of spurious edges corresponding to noise [7], which is often the case with conventional gradient-based techniques. The three edge strength values used as fuzzy system inputs were fuzzified using Gaussian membership functions [7]. Fuzzy if-then rules are applied to modify the membership to one of low, medium, or high classes. Finally, Mamdani defuzzifier method is applied to produce the final edge image.

D Edge Detection Technique Based on Fuzzy Logic

In this paper, emphasis has been to develop a very simple and small but a very efficient [8], fuzzy rule based edge detection algorithm to abridge the concepts of artificial intelligence and digital image processing. We have used the smallest possible mask 2×2.The algorithm has been developed in MATLAB environment. Comparisons were made with the various other edges detection algorithms that have already been developed. Displayed results have shown the accuracy of the edge detection using the fuzzy rule based algorithm over the other algorithms. The fuzzy rule based algorithm has been successful in obtaining the edges that are present in an image after the implementation and execution with various sets of images.

V. CONCLUSION

Image denoising plays an important role in image processing. The image corrupted by different kinds of noises is a frequently encountered problem in image acquisition and transmission.. Hence for proper interpretation of image information the images must denoised. So we find fuzzy logic based technique which provides robust and efficient gray image denoising technique. Although good denoising techniques are already available for image denoising like median filter and average filter, while most of the time it has been found that all these filters provide good results but not able to preserve image edges during denoising. Since edges are very important characteristics it must be preserved during denoising process.

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