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A Survey on Fuzzy based Image Denoising Methods

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Abstract: **Images are very useful source of information which is often degraded in the presence of noise. Noise present in the image hides the important information. So, to retain the quality of the image we need to remove noise. Noise filtering is one of the important tasks of image processing techniques. Several denoising methods are proposed to improve the quality of image by removing different kinds of noises. Each method has its own applicability, assumptions, advantages and disadvantages. This work comprises study of some traditional filters and fuzzy filters. A comparative study of Image Denoising filters and importance of fuzzy filters has been enlisted.**

Keywords: Image denoising, spatial domain, transform domain, Fuzzy logic, Fuzzy filters.

I. INTRODUCTION:

Digital images are used as a powerful means of communication in the era of information and communication technology. Digital image plays a very important role in our day to day life in applications like Satellite television, medical image analysis, digital cameras, as well as in the areas of research and technology [10], [16]. On the process of image capturing and acquisition image sensors usually get affected by noise due to imperfect instruments, poor weather conditions, transmissions errors and compression. Thus image denoising becomes a pre-processing task in image processing before the image is analyzed. Image denoising is necessary to enhance the quality and structure of original image which has been degraded by noise. Noise can be modeled as Gaussian noise and Impulse noise (salt-and-pepper noise) [1]. Gaussian noise is uniformly distributed over the signal and salt-and-pepper noise; the noisy pixels can take only minimum (0) and maximum (1) value. Other types of noises are speckle noise, amplifier noise, shot noise etc. Denoising is still a challenge in image processing because it introduces artifacts and can cause severe blurring. In this paper various denoising methods have been studied including traditional methods and fuzzy methods. The advantage that fuzzy logic provides over the other methods is briefly described.

II. CLASSIFICATION OF IMAGE DENOISING METHODS:

The main aim of any denoising method must be to provide visually good quality image, by removing the noise and preserving the structure of the image. Based on the various works done in the field of image denoising, the method can be categorized as; traditional filtering methods [2] and Fuzzy filtering methods [4] – [9], [17] – [18].

A. Traditional Filtering Methods:

This method used the traditional algorithms for removing the noise from images. We further divide this method in two domains: spatial domain and transform domain filter. Each method has its own set of advantages and drawbacks.

1. Spatial Domain Filtering: The spatial filters are used to remove the additive noise (Gaussian noise) and impulse noise. This method has fast processing speed but is unable to preserve edges resulting in poor image quality. It is a type of low pass FIR filter which performs neighborhood operations on the selected input pixel window to get the output values. They are subdivided in two types: Linear filters and Non-linear filters. The linear filters such as mean filter and Weiner filter works best with Gaussian noise filtering where as the non-linear filters like Median and Weighted Median filters are used to remove the impulse noise present in the image.

2. Transform Domain Filtering: This method provides better filtering results than the spatial domain filtering. Contrary to spatial domain methods these methods preserves the edges and texture of the image. The denoising method in transform domain requires transforming the original image or signal to another domain and applying denoising procedures, the output is retrieved by applying inverse transformation. The fast Fourier transform (FFT) and wavelet transform are the most popular transform used in this methods. Wavelet transforms are multiresolution decompositions used to analyze images. They are a powerful tool for enhancing the structure and features of an image. Wavelet transform techniques [15] are further divides as linear filtering, Non-linear Threshold Filtering, wavelet coefficient model and Non-orthogonal wavelet transform. Some filters which fall under this category are Weiner filters, VisuShrink, BayesShrink, SureShrink, etc.

B. Fuzzy Filtering Methods:

The fuzzy logic was introduced by Lotfi A. Zadeh in 1965 [3], a new logic that deals with the uncertain and vague data to form Fuzzy If-then rules which is applied on the data to get desired output. Fuzzy logic helps in dealing with the complicated problems in a much simpler way by allowing the use of linguistic variables instead of numerical relations. The fuzzy logic based denoising algorithms provides a valuable tool to deal with the uncertain nature of the noise. The Fuzzy filtering is a relatively young theory, which has been exploited to remove the drawbacks provided by the classical filters. Since each filter algorithm has its own

approach, advantages and disadvantages so numerous work has been done using fuzzy logic in image denoising. Some of the classical fuzzy filters and full fuzzy filters have been studied are: GOA filter [11] is used for the removal of the Gaussian noise which uses fuzzy rules to detect the gradient value. The small gradient value represents noise and large gradient value is the image structure. It is best for Gaussian noise removal. The next filter for removing Gaussian noise for gray scale image is Fuzzy Shrink filter [12] in the wavelet domain. It outperformed the fuzzy non-wavelet methods such as Histogram Adaptive Fuzzy filter (HAF). For impulse noise removal the Fuzzy Impulse Noise Detection and Reduction filter (FIRDM) [4] gave good results. It works in two stages. The detection phase detects for the noisy pixel present in the image and the filtering phase filters for the noise. Later Fuzzy Random Impulse Noise Reduction filter (FRINR) also achieved the goal of removing random valued noise using a two step filter using fuzzy logic [13].

III. STUDY OF FUZZY FILTERS:

The other fuzzy filters are studied and compared in terms of statistical parameters for Gaussian noise and impulse noise and are classified based on the type of noise they deal with.

A. Fuzzy Filters for Gaussian Noise Removal:

1. MRF Image Denoising Based on Fuzzy Classification [5]: This method presents the modification made in the original Markov Radom Fields (MRF) in execution time and removal of additive white noise. Applying fuzzy classification to the MRF saves the extra processing time taken by the Markov method for denoising the gray scale image. The image sub-block is fuzzy classified by its statistical characteristics, the smooth regions and the edge regions are identified for processing the image pixels having different regional characteristics. The fuzzy concept is used in the process of soft thresholding to preserve the edges. The original image is restored by the models with different prior energy functions. The performance of the FC-MRF is better than MRF and is compared in the table I.

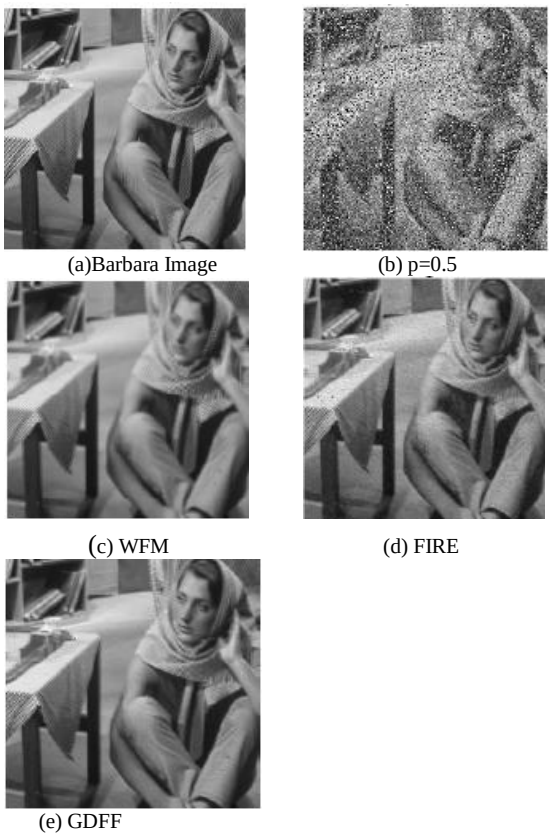
TABLE 1. The Comparative Results Tested For the Image of Additive White Noise.

Parameters	FC-MRF	MRF
PSNR	37.64	36.06
Running Time	18.78 s	31.5 s

2. Gradient Detecting Fuzzy Logic Based Algorithms (GDFF) [6]: This is a new approach using fuzzy logic based on gradient detection of the pixels, for the removal of Gaussian noise in a gray scale image. The image gradient can detect the edge information, and enhances the image pixels in the edge direction. IN GDFF, the detection phase selects different fixed filtering sub windows to process the input signal by linear denoising. A 3×3 window is selected in this model and gradient values are evaluated in each direction. Then with the help of the edge information a membership function is established that modifies the denoised results. Experiment results show that the GDFF performs better than WFM and FIRE filters in terms of PSNR. PSNR values of the GDFF are very stable for noise probability from 0 to 1.

TABLE 2. PSNR compared at noise rate 50% and 80%.

			Lena	Barbara	Cameraman
PSNR (dB)	GAUSS NOISE 50%	Noise	12.7493	13.6494	12.3149
		FIRE	18.6331	21.0631	18.0931
		WFM	22.1335	23.0935	22.1735
		GDFF	25.0793	26.3793	24.7793
	GAUSS NOISE 80%	Noise	9.2153	10.2315	9.1407
		FIRE	12.3229	13.7027	11.0229
		WFM	14.0824	16.9824	13.8824
		GDFF	22.2035	24.0395	21.4035



(a)Barbara Image (b) p=0.5 (c) WFM (d) FIRE (e) GDFF

Figure1: Results of different filters for Barbara Image.

3. A Fuzzy non-linear Technique for Image Denoising [7]: A non-linear fuzzy technique is presented for the enhancement of the image corrupted with the Gaussian noise. The edge information is also preserved using this technique. The idea behind this filter is to average a pixel using other pixel values from its neighborhood and taking care of edge using block size. The average value is derived for each direction corresponding to neighbor pixels using fuzzy rules. The fuzzy derivative is found of the pixel from its neighborhood from which membership function is calculated. The small fuzzy derivative is caused due to noise and large fuzzy derivative is mainly caused by the edges. Fuzzy smoothing is done which provides clarity of the image. Simulation results show that the proposed filter outperforms the Non Local means method and other filters for both the MSE and visual quality for the Gaussian noise.

TABLE 3: Comparison of the MSEs of Restored Lena Image

Filter Type	Mean Square Error (MSE)
Mean Filter (3×3)	382
Median Filter (3×3)	244
Non Linear-mean Method	126
Proposed Non Linear fuzzy Method	112

B. Fuzzy Filters for Impulse Noise Removal:

1. Impulse Noise Detection and Reduction using Fuzzy Logic and Median Heuristic Filter [8]: This is a new two step technique which is used to remove impulse noise from gray scale images. In the first step fuzzy reasoning is applied to detect noisy pixels with lowest uncertainty and in the second step noisy pixels are replaced with a heuristic median filter. The heuristic median filter is similar to trim median filter but in this method uses average of neighbor pixels and heuristic filtering is applied in three steps to replace noisy pixels. Result showed that the Heuristic median fuzzy filter performed better than the other filters in terms of PSNR, execution time and visual quality when compared with Adaptive Alpha Trim, Standard Median Filter and Median Based Fuzzy Filter for various images.

TABLE 4: Results for different Images

		10% Noise		30% Noise	
Method	*Parameter*	*Lena*	*Boat*	*Lena*	*Boat*
Adaptive Alpha Trim	PSNR	26.27	25.71	21.25	21.12
	Time (sec)	10	10	10	10
Standard Median Filter	PSNR	41.59	38.39	33.75	31.31
	Time (sec)	1	1	1	1
Median Based Fuzzy	PSNR	38.43	35.88	31.16	27.84
	Time (sec)	1	1	4	4
Heuristic Median Fuzzy	PSNR	45.38	41.87	39.98	36.39
	Time (sec)	3	3	7	7

2. Fuzzy Switching Median Filter [9]: The fuzzy median switching filter (FSM) is used for removing salt and pepper noise while preserving the texture of the image. The FSM filter is divided in two modules. The first module detects the salt and pepper noise from an image and the second module is for fuzzy noise cancellation. Use of fuzzy sets has reduced the complexity in computation provided by the traditional methods. In this work, we define a low level salt-and-pepper noise with probability lying in the range 0 and up to $p = pw + pb = 0.25$, where $pw = pb$. If $p = 0.45$ or higher, the image is regarded as corrupted by high level of salt-and-pepper noise. Otherwise, the image is said to be corrupted by a moderately high level of salt-and-pepper noise.The FSM filter is compared with various classical filters and it performed better than the classical filters.

TABLE 5: Comparison of Results for various Methods in MSE using Images LENA corrupted by 20% Impulse Noise and BABOON corrupted by 40% Impulse Noise.

Parameters	LENA MSE	BABOON MSE
Noisy Image	3698.51	7332.24
Luo Filter	2094.00	6151.94
Laplacian SM 5×5	27.35	357.93
Median Based 5×5	29.97	466.73
FIRE	33.94	406.24
PWL-FIRE	15.10	251.36
FSM (Proposed)	12.42	248.28

IV. CONCLUSION:

In this work, a relative study of Image Denoising filters for gray scale images has been done. The classification of Image denoising methods and an overview of traditional methods have been presented. The main goal is to focus on the advantages that fuzzy filters provide over the traditional filters for removing various types of noises from the image. The various fuzzy filters work with specific type of noise like FIRDM, FIRE, and FSM performs better with impulse noise. GOA, GDFF, MRF filters give good performance for removing Gaussian noise. The fuzzy filters perform best with various types of noises as compared to traditional methods. The quest is to search for a fuzzy based universal filter that can remove all types of noises from the image.

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