

Efficient Image Denoising Algorithm for Gaussian and Impulse Noises

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ABSTRACT: One of the fundamental challenges in the field of image processing and computer vision is image denoising, whose underlying goal is to estimate the original image by suppressing noise from a noise-contaminated version of the image. Image noise may be caused by different intrinsic and extrinsic conditions which are often not possible to avoid in practical situations. Therefore, image denoising plays an important role in a wide range of applications via image restoration, image registration, visual tracking, image classification and image segmentation, where obtaining the original image content is crucial for strong performance. While many algorithms have been proposed for the purpose of image denoising, the problem of image noise suppression remains an open challenge, mainly in situations where the images are acquired under poor conditions where the noise level is very high. This paper deals with comparing the denoised images obtained from various denoising algorithms, by introducing gaussian and impulse noises to the image. The algorithms used are Fuzzy rule based filtering algorithm and Decision based Switching Median filter algorithm which denoises the noisy image and comparison is made in terms of quality and smoothness.

KEYWORDS: Denoising, Fuzzy rule based filters, Noise suppression, Noise models, Switching median filters.

I. INTRODUCTION

Digital image processing aims at enhancing the potential visual information for human interpretation and processing digital images to make them combat for perception by autonomous machine vision systems. Image acquisition by the sensors on image capturing devices and/or the transmission of digital images through communication channels is often affected by impulse noise which is most commonly referred to as salt and pepper noise and/or by gaussian noise. Ganchao Liu et al in their paper has studied about various noises on a similarity model [1]. When a digital image is contaminated by the noise, it hardly degrades the quality. In a motive to restore the images corrupted by impulse noise and gaussian noise, the noise removal becomes an essential pre-processing step in digital image processing that usually enhances the quality of the image for further processing by machine vision systems. Aparna Sarkar et al [2] and Ayush Kumar et al [3] has made studies on salt and pepper noise and how its effect on the sample models. The processing of digital images for the restoration of images contaminated by various kinds of noise has been drawing a significant attention of the researchers over the last few decades. In an attempt to suppress these noises from the corrupted image various kinds of noise removal filters have been proposed. The wavelet transform, curvelet transform and wave atom transform are the efficient transforms for image denoising algorithms. Some of the techniques are using fuzzy logic and other tools. Jezebel Priestley J et al [4] has discussed about the image restoration techniques required for these. Most of the noise removal techniques suggested till now is based on what type of noise is introduced. Also the application to which the image and video are to be used, decides the required noise removal algorithm. Here three such denoising algorithms are proposed and are c

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 4, April 2016

ompared so as to determine a better denoising technique which can be implemented for both impulse and gaussian noises. Rai et al [5] and Hao- Tian Wu et al [6] through their paper gives an idea on the application of various image denoising models and how their impact on the various models.

In this paper, the better image denoising technique is found for the removal of gaussian and salt and pepper noises in an image using the decision based median filtering and fuzzy rule based filtering which has been explained by Rafael et al[7] for the various noise densities. Several non-linear filters have been proposed to remove the salt and pepper noise from the images. Among these standard median filter has been a reliable method to remove salt and pepper noise without damaging the edges. The main disadvantage of standard Median Filter (MF) is that it is only effective in low noise densities. Adaptive Median Filter (AMF) whose effectiveness is tested by Vasanth et al[8] is also performing well at low noise density but at high noise density it blurs the image. To overcome these drawbacks, different algorithms such as Decision Based Switching Median Filter (DBSMF), abstracted from the idea by Arbinda Dash et al [9] and fuzzy ruled based filtering is algorithm is designed and compared for finding the effective algorithm for the removal of impulse and gaussian noises. The images are considered with various noise densities and its image quality factors such as Peak Signal to Noise Ratio (PSNR) and Mean Squared Error (MSE) values are estimated.

II. RELATED WORK

2.1 Decision Based Switching Median Filter (DBSMF)

The removal of noises using the Decision Based Switching Median Filter (DBSMF) consists of two stages. They are the noise pixels detection stage and the filtering of corrupted pixels. The noise detection stage build a binary decision map which denotes whether the current pixel have the intensity value either 0 or 255. If the current pixel value is found to be 0 or 255, the binary decision map hold the binary 1 to indicate that the pixel is being corrupted. On the other hand, for the pixels with intensity value lying between the range 0 and 255, the decision map hold binary 0 which indicates that the current pixel is uncorrupted. The algorithm for DBSMF is described below.

Step 1: Select the processing pixel in the image read.

Step 2: If $0 < P_{ij} < 255$, then P_{ij} is considered as uncorrupted pixel and is left unchanged.

Step 3: Otherwise, calculate the median of the pixels in the window and replace processing pixel by the median value.

Step 4: Move the window to the next pixel in the image. And repeat steps 1 to 3 until all the pixels in the entire image are processed.

2.2 Fuzzy Rule Based Filtering

Fuzzy image processing is not a unique theory. It is a collection of all approaches that understand, represent and process the images, their segments and features as fuzzy sets. The representation and processing depend on the selected fuzzy technique and on the problem to be solved. Fuzzy image processing has 3 main steps: image fuzzification, modification of membership values, and if necessary, image defuzzification. It is used in many applications e.g., object recognition, sense analysis, etc.

In this approach, first the filtering process is started by looking at the edges. Main aim is to make distinction between the local variations due to noise and due to image structure. For that consider the 3×3 neighborhood of pixel (x, y) . A simple derivative with respect to the central pixel (x, y) is calculated by finding difference between the central pixel and its neighbor in the direction D (where $D \text{ dir} = \{N, S, W, E, NE, SE, SW, NW\}$). This derivative value is denoted as in the equation (1) and (2):

$$\Delta_{NW}(x, y) = F(x-1, y-1) - F(x, y) \quad (1)$$

$$\Delta_N(x, y) = F(x, y-1) - F(x, y) \quad (2)$$

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After this, fuzzy filtering is performed by calculating the fuzzy derivatives. In order to find out the value of fuzzy derivative for a particular direction, the values of $\Delta_{NW}(x, y)$, $\Delta_{NW}(x-1, y+1)$ and $\Delta_{NW}(x+1, y-1)$ are calculated. If any two of the derivative value are small, it is safe to assume that no edge is present in the considered direction and this variation is due to the noise. The algorithm is described as follows.

Step 1: Read the image to be processed

Step 2: Choose a mask of 5*5 size; For each central pixel, 8 neighbours in the eight directions are considered

Step 3: Calculate the fuzzy derivative values for a particular direction

Step 4: Calculate the correction term and add it to the central pixel of the selected mask

Step 5: Repeat the process till each and every pixel of the image is traversed

III. SIMULATION RESULTS

The image denoising using Decision based Switching Median Filter and Fuzzy Rule Based Filtering for various noise densities in the images lena.jpg and indddex.jpg with impulse and gaussian noises are tested. The images are of 512*512 8-bit/pixels with noise densities from 20% to 90% and their performance is quantitatively measured by Mean Squared Error (MSE) and Peak Signal to Noise Ratio (PSNR) values.

Let $f(x,y)$ be the original image with size $M \times N$ and $f'(x,y)$ be the restored image with the same size. The MSE and PSNR values are given by the equations (3) and (4) respectively:

$$MSE = \frac{1}{MN} \sum_{xy} (f'(x, y) - f(x, y))^2 \quad (3)$$

$$PSNR = 10 \log_{10} \left(\frac{255^2}{MSE} \right) \text{ (dB)} \quad (4)$$

3.1 Impulse Noise Image Result

The images obtained in decision based switching algorithm for impulse noise at the noise density of 50% are shown in the fig. 1.

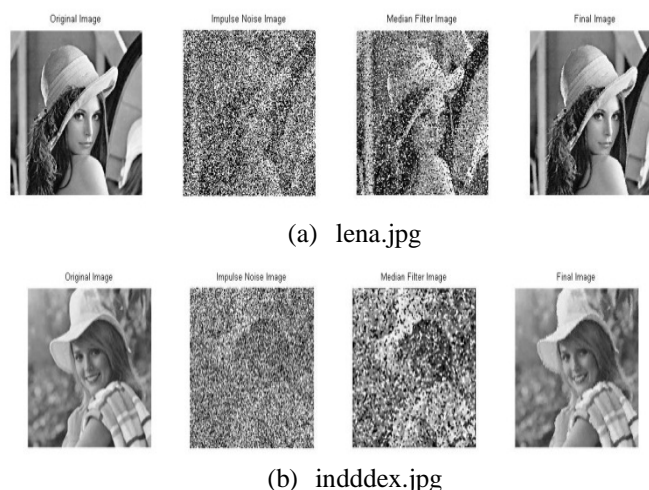


Fig1: Performance of decision based switching median algorithm with noise density of 50% for impulse image

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Vol. 5, Issue 4, April 2016

The images obtained in fuzzy rule based algorithm for impulse noise at the noise density of 50% are shown in the fig. 2.

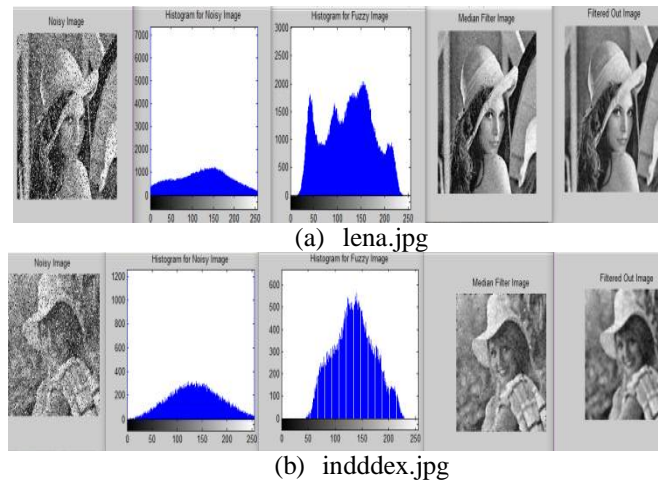


Fig 2: Performance of fuzzy rule based algorithm with noise density of 50% for impulse image

The calculated values of MSE and PSNR for the impulse noise images lena.jpg and indddex.jpg are presented in the Tables I – II.

Table I MSE value comparison at various noise densities of the image lena.jpg and indddex.jpg with impulse noise

Noise Density (%)	lena.jpg			indddex.jpg		
	Median Filter	DBSMF	Fuzzy	Median Filter	DBSMF	Fuzzy
20	12.36	13.06	5.18	12.68	13.06	5.18
30	10.51	30.38	5.42	11.74	30.38	5.42
40	8.35	28.41	5.51	8.85	28.42	5.51
50	4.87	26.34	4.15	4.47	26.34	4.15
60	2.98	24.60	4.21	2.98	24.59	4.21
70	2.42	22.35	4.36	2.42	22.27	4.36
80	1.74	19.84	3.66	1.114	19.51	3.66
90	1.08	16.96	2.76	1.08	16.12	2.76

Table II PSNR value comparison at various noise densities of the image lena.jpg and indddex.jpg with impulse noise

Noise Density (%)	lena.jpg			indddex.jpg		
	Median Filter	DBSMF	Fuzzy	Median Filter	DBSMF	Fuzzy
20	25.69	33.09	14.01	26.19	33.09	14.03
30	22.14	30.38	14.43	23.14	30.38	14.45
40	18.31	28.41	14.851	18.31	28.41	14.76
50	14.81	26.34	13.29	14.81	26.34	13.22
60	12.23	24.60	13.607	12.23	24.60	13.34
70	9.98	22.35	13.36	9.98	22.35	12.85
80	8.10	19.84	12.676	8.10	19.84	12.25
90	6.68	16.96	11.728	6.68	16.96	11.403

3.2 Gaussian Noise Image Result

The images obtained in decision based switching algorithm for gaussian noise at the noise density of 50% are shown in the fig. 3.

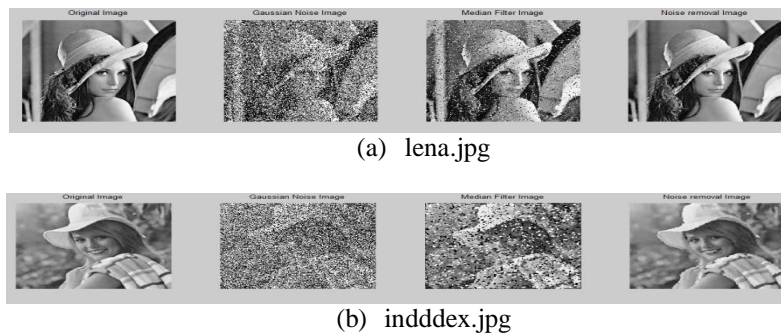


Fig 3: Performance of decision based switching median algorithm with noise density of 50% for gaussian image

The images obtained in fuzzy rule based algorithm for gaussian noise at the noise density of 50% are shown in the fig. 4.

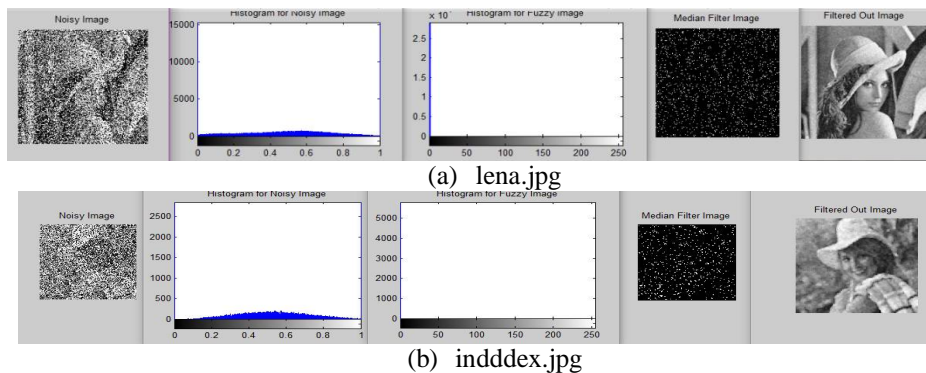


Fig 4: Performance of fuzzy rule based algorithm with noise density of 50% for gaussian image

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 4, April 2016

The calculated values of MSE and PSNR for the gaussian noise images lena.jpg and indddex.jpg are presented in the Tables III - IV.

Table III MSE value comparison at various noise densities of the image lena.jpg and indddex.jpg with gaussian noise

Noise Density (%)	lena.jpg			indddex.jpg		
	Median Filter	DBSMF	Fuzzy	Median Filter	DBSMF	Fuzzy
20	0.05	0.15	1.80	0.05	0.15	1.80
30	0.07	0.17	2.08	0.08	0.21	2.08
40	0.12	0.24	2.62	0.11	0.32	2.62
50	0.17	0.39	3.53	0.14	0.51	3.53
60	0.15	0.65	4.11	0.17	0.79	4.11
70	0.17	1.06	4.62	0.19	1.19	4.62
80	0.24	2.08	5.34	0.22	1.73	5.34
90	0.29	5.09	5.81	0.25	2.26	5.18

Table IV PSNR value comparison at various noise densities of the image lena.jpg and indddex.jpg with gaussian noise

Noise Density (%)	lena.jpg			indddex.jpg		
	Median Filter	DBSMF	Fuzzy	Median Filter	DBSMF	Fuzzy
20	20.04	40.75	15.01	20.04	40.82	15.01
30	18.22	32.17	14.43	18.26	31.87	14.43
40	16.98	27.03	14.51	16.98	26.65	14.51
50	16.05	23.13	12.29	16.07	23.21	12.29
60	15.25	20.12	12.04	15.26	20.23	12.04
70	14.57	17.72	12.41	14.56	17.64	12.41
80	13.99	15.82	11.26	14.02	15.86	11.26
90	13.48	14.28	10.78	13.49	14.37	10.78

From the Tables I- IV, it is seen that for the images with impulse noise, the fuzzy based values have better performance criteria in the high densities alone. Compared to this, decision based switching median filter gives the average range of values for both the impulse and gaussian noises at all the noise densities without affecting the quality of the image.

VI. CONCLUSION

In this paper, algorithms created for impulse and gaussian noises, the decision based switching median filter works well for impulse noises at both high and low noise densities, though they do not go well with gaussian noises. The fuzzy based filtering performance is better at high noise densities. Thus, we can conclude that the usage of decision based switching median filter suits to both algorithms to an extent.

In future, this paper can be modified by implementing any cascading of these algorithms or by finding new algorithms which can improve the quality of images affected by both impulse and gaussian noises at all the noise density ranges.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

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