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Iterative Switching Filter for High Density Noise Removal

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Abstract— This paper proposes an efficient filter for the restoration of images that are corrupted by high density of impulse noise. In this method an iterative switching filter is used that switches between two cases depending on the noise percentage in the input image. For low noise percentage it searches for the noise-free pixels within a small neighborhood. The noisy-pixel is then replaced with the average estimated from noise-free pixels. For high noise percentage weighted median is used to replace the corrupted pixels. The iterative process continues until all noisy-pixels of the corrupted image are filtered. The proposed filtering method is tested using standard test images and found to be more efficient than already existing high density noise removal techniques.

Index Terms— Salt-and-pepper Noise; noise-free pixel; Iterative Swiching Filterr; Noise Adaptive Weighted Switching Median Filter.

1 Introduction

NOISE is a factor affecting the image, which is mainly produced in the processes of image acquisition, storage and transmission, thereby degrading the quality of images; therefore a common problem in applied science and engineering is the restoration of the corrupted images included in the image. Image filtering not only improves the image quality but also is used as a pre-processing stage in many applications including image encoding, pattern recognition, image compression, etc.There are many methods for removal of impulse noises from the images. Usage of linear filters such as averaging filters produces blurring of the images. Non linear filters such as median filters are the most popular technique for removing impulse noise because of its good denoising power and computational efficiency. However most of the median filters are implemented uniformly across the image and thus tend to modify both noisy and noise free pixels. Consequently the effective removal of impulse noise is often accomplished at the expense of blurred and distorted features thus removing fine details in the image.

Switching median filters are shown to be simple and yet more effective than uniformly applied methods such as median filters [1] [2]. There are different methods for impulse noise detection: fuzzy approaches [4-6], neural approaches [7] and boundary based approaches [8]. Among the three categories boundary based approach [8] is preferred due to its simplicity compared to computational complexity and system structure of other two categories. The filtering window size is chosen adaptively and depends on the percentage of noise that corrupts the image[9].

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The initial filtering window size is taken as 3×3 and maximum window size is chosen depending on the percentage of noise that corrupts a local region around the detected noisy pixel in the image. The noisy pixels are replaced by the weighted median value of uncorrupted pixels in the filtering window.

In the proposed method an iterative switching filter is proposed which gives better performance measures when compared to other existing methods and for high density noisy images it preserves the edges and finer details of the image. Section II explains the proposed method and the algorithm for implementation. Performance analysis is done in Section III while the result analysis and comparison is done in Section1V.

2 . Iterative Switching Filter

The noise removal technique as proposed in Iterative Switching Filter is capable of removing high density of impulse noise effectively while preserving the fine image details for low noise density images while for high noise density images the fine details can be retrained. The different stages in this filtering process are the following:-

2.1 Construction of detection Map

In this step, the detection map is constructed from the input noisy image *X*[3]. In case of salt-and-pepper noise, the maximum and the minimum intensity values of the image dynamic range [Imax, Imin] provide information about the corrupted pixels .The detection map is computed from the noisy image as follows:

$$d_{i,j} = \begin{cases} 1, & if \quad x_{i,j} = I_{\max} \\ 1, & if \quad x_{i,j} = I_{\min} \\ 0, & \text{otherwise} \end{cases}$$

The entries of “1” and “0” in the detection map *D* represent the noisy and the noise-free pixels, respectively. This map provides useful information about the noise intensity in the corrupted image.

2.2 Detection of Noise Density

Inorder to process the image the noise density present in the image should be identified. The filtering is done based on this value. The calculation of noise density *p*, for a local window *K*×*K* is given as shown below:

$$p = \frac{\sum_{i,j=1}^{k} D(i,j)}{K^2}$$

2.3 Filtering Process

In this proposed filter method there are two cases. Depending on the noise density the filter switches between the two cases. For noise density less than or equal to 40% the noisy pixel is replaced with the average of the noise free pixels in the 3X3 window. For higher noise density the corrupted pixel is replaced with the weighted median of the pixel is replaced with the weighted median of the uncorrupted pixels. The weight assign is 3.This filtering process is continued until all the noisy pixels have been removed.

2.4 Proposed Algorithm

The proposed iterative switching filter the noise density in the input image is identified. A detection map is created which is a binary matrix of zeros and ones where the noisy pixels in the input image are represented as ones and noise free as ones. Depending on the noise density either average of the noise free pixel is found and replaces the noisy pixel otherwise weighted median is found and replaces the noisy pixel.

STEP1: Obtain the noise image as input.

STEP 2: Construct the detection map, D. Detection map is a binary matrix where zeros represent noise free pixels and ones represent the noisy pixels.

STEP 3: Identify the noise density of the image using detection map.
Noise density= (sum of the uncorrupted pixels of detection map)/size of D.

STEP 4: Check the detection map to find if there are any noisy pixels. If so do
(i) Consider each pixel, Pi,j for processing.
(ii) If Pi,j is noisy go to step 6 otherwise go to step 4.
(iii)Consider the 3X3 neighbourhood of the pixel and construct a vector R which contains the uncorrupted pixels.
(iv): If the noise density is less than or equal to 40% go to step 10 otherwise go to step 13.
(v) Compute the estimate which is the average of vector R and assign it to G(I,j).
(vi): If the number of uncorrupted pixels is greater than or equal to 3 go to step 9 otherwise go to step 13.
(vii): Compute G(I,j) as the weighted median of R.

STEP 5: Assign P-G and Update the detection map.

STEP 6: Check the detection map to find if there are anymore noisy pixels. If so go to step 4 otherwise go to step 7

STEP 7: Display the processed image as output.

STEP 8: Stop

3 Performance Measure

The performance of the restoration quantified using peak signal-to-noise ratio (PSNR), structured similarity index (SSIM) and image enhancement factor (IEF), is defined as follows. The method has been compared with the NAWSM [4] and is found to give better results for the various performance measures. For high density noisy images such as 90% noise the resultant image preserves the edges and finer details in the resultant image.

$$PSNR = 10 * \log 10(255^2 / MSE)$$
$$MSE = \sum_{m,n} [O(m,n) - R(m,n)]^2 / (M * N)$$
$$SSIM = L(O,R) * C(O,R) * S(O,R)$$
$$L(O,R) = (2\mu_O\mu_R + C_1)/(\mu_O{}^2 + \mu_R{}^2 + C_1)$$
$$C(O,R) = (2\sigma_O\sigma_R + C_2)/(\sigma_O{}^2 + \sigma_R{}^2 + C_2)$$
$$S(O,R) = (\sigma_{OR} + C_3)/(\sigma_O\sigma_R + C_3)$$
$$C_1 = (K_1 * G)^2, C_2 = (K_2 * G)^2, C_3 = C_2/2$$
$$G = 255; K_1, K_2 >> 1, (K_1 = 0.001, K_2 = 0.002)$$
$$IEF = \left(\sum_{m,n} [P(m,n) - O(m,n)]^2\right) \Big/ \left(\sum_{m,n} [R(m,n) - O(m,n)]^2\right)$$

where *O* is the original Image, *R* is the restored image, *P* is the corrupted image, *MSE* is the mean square error, *M* × *N* is the size of the image, *L* is the luminance comparison, *C* is the contrast comparison, *S* is the structure comparison, μ is the mean and σ is the standard deviation.

4 Result And Analysis

The performances of both filters have been evaluated qualitatively and quantitatively through experimental analysis. Although extensive simulations were carried out using standard test images, only performance evaluation using images such as Lena image of size 512×512, Boat image of size 512 x 512 are explained in this section.

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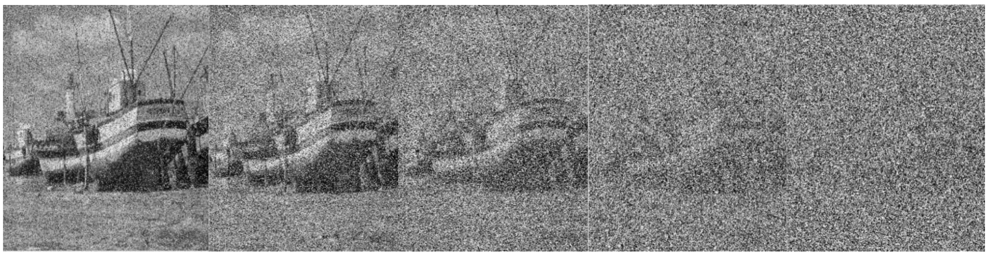
(a) (b)

Figure 1. Standard test image of (a) BOAT, (b) LENA



(a) (b) (c) (d) (e)

Figure 1. Images corrupted with salt-and-pepper Noise(a)with 20%, (b) with (40%), (c)with 60%, (d) with 80% ,(e)with 90%

(a) (b) (c) (d) (e)

Figure 2.(a)-(e) Results after the NAWSMF filtering for the respective noisy images

(a) (b) (c) (d) (e)

Figure 3.(a)-(e) Results after the ISF filtering for the respective noisy images

(a) (b) (c) (d) (e)

Figure 4. Images corrupted with salt-and-pepper Noise(a)with 20%, (b) with (40%), (c)with 60%, (d) with 80% ,(e)with 90%

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(a) (b) (c) (d) (e)

Figure 5 .(a)-(e) Results after the NAWSMF filtering for the respective noisy images

(a) (b) (c) (d) (e)

Figure 6 .(a)-(e) Results after the ISF filtering for the respective noisy images

Table 1.Peformance comparison for the BOAT image corrupted with various Noise Density

Noise (%)	Tenengrad		PSNR		SSIM		IEF	
	ISF	NAWSMF	ISF	NAWSMF	ISF	NAWSMF	ISF	NAWSMF
20	259648	259593	34.8716	33.8250	0.9951	0.9938	174.3444	137.0092
40	259646	259373	30.3228	30.1078	0.9861	0.9853	121.9887	116.0960
60	259499	257868	27.5208	27.3871	0.9733	0.9723	96.3149	93.3949
80	257686	255801	24.8644	24.8174	0.9506	0.9500	69.5014	68.7536
90	248762	251933	22.7228	22.1543	0.9194	0.9075	47.8093	41.9427

Table 2.Peformance comparison for the LENA image corrupted with various Noise Density

Noise (%)	Tenengrad		PSNR		SSIM		IEF	
	ISF	NAWSMF	ISF	NAWSMF	ISF	NAWSMF	ISF	NAWSMF
20	258087	258068	38.6426	37.2887	0.9981	0.9973	416.0056	304.5838
40	257803	257324	33.4470	33.4533	0.9936	0.9936	254.3767	254.7427
60	257287	254940	30.6749	30.6845	0.9878	0.9878	199.7483	200.1892
80	254393	251840	27.4158	27.6603	0.9741	0.9755	125.9112	133.2042
90	244502	247354	25.1705	24.5471	0.9565	0.9496	84.0864	72.8421

The performance measure (PSNR) of ISF is comparatively greater than that of NAWSMF. For 90% noisy image, ISF method preserves the finer details and edges of the image. The tenengrad value of ISF from the above tables is greater than that of NAWSMF. From these values also we can conclude that ISF method preserves the edges of the image efficiently. The performance measures, IEF and SSIM are also shown in the tables.

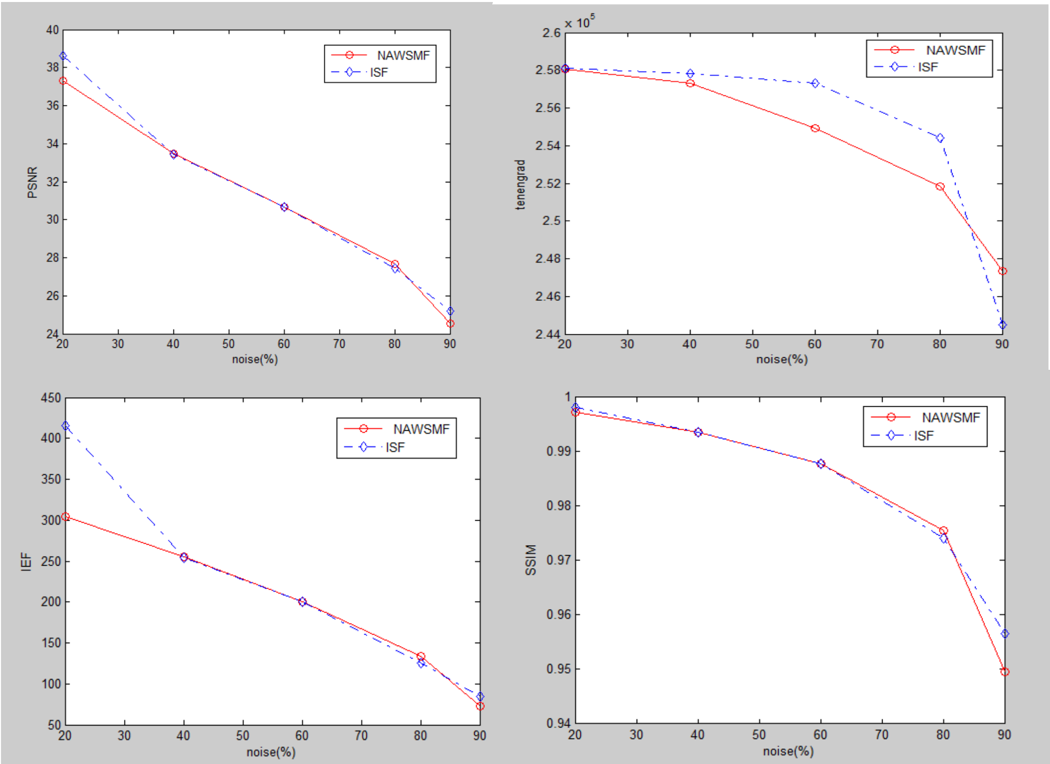

Fig. 5. Graphical representation of various performance measures for lena image corrupted with salt and pepper noise.

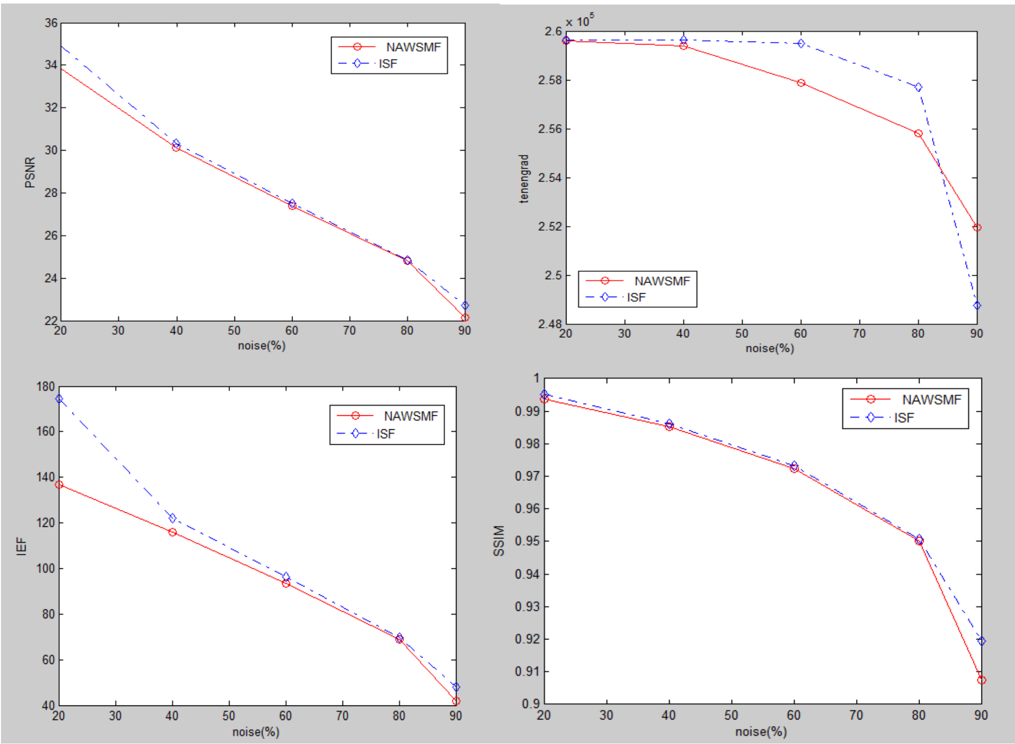

Fig. 5. Graphical representation of various performance measures for boat image corrupted with salt and pepper noise

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