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Image De-noising Performance of Rank filters

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Abstract: In image processing, the rank filters are used to yield better noise removal ability for salt & pepper type noise. But they won't reproduce the images exactly for high noise density conditions. During image processing, varying noise density surely affects the de-noising performance of the processing system. So, The Noise removal ability of system should be improved. Proper rank filter selection would be important for this. Otherwise we may lose our precise information. In this work, three rank filter algorithms are compared to estimate their performance in high noise density. We can infer the filters response from the results shown. Better Filtering selection can be achieved using PSNR values presented from original and de-noised images**.**

Keywords: Image De-noising, Median filter, Adaptive median filter, Hybrid median filter, PSNR, Salt & pepper noise.

I. INTRODUCTION

In image enhancement and restoration process, there is always wide space to spatial filtering which divides into linear and non-linear filtering to noises. Even though linear image enhancement tools are often adequate in many applications, significant advantages in image enhancement can be attained if nonlinear techniques are applied. Nonlinear methods effectively preserve edges and details of images, whereas methods using linear operators tend to blur and distort them. Besides, nonlinear image enhancement tools are less susceptible to noise. Noise is always with us because of the physical randomness of image acquisition and processing systems. An Image noise impact is primarily characterized by its mean, variance function. These two determines the noise density values. In this paper, filters are studied under different noise density values for their response. Results are shown from the impulse (salt & pepper noise) noise mixed images and other noise types also.

Outline of this paper is as follows: In the first section, what are image noises, how de-noising performance calculated, different rank filters and algorithms' going to be examined is discussed. Section third gives simulation results, last section gives the conclusion.

II. NON LINEAR FILTERS FOR DENOISING

Various filtering techniques have been proposed for removing impulse noise in the past and it is well-known that linear filters could produce serious image blurring. As a result, nonlinear filters have been widely exploited due to their much improved filtering performance, in terms of mixed noise attenuation and edge / details preservation. Rank filters are non linear spatial filters whose response is based on ordering (ranking) the pixels contained in the image area encompassed by the filter, and then replacing the value of the center pixel with the value determined by the ranking result. So that they are known as Order-Statistics filters or ranking filters. This performance analysis is made with Median filter, Adaptive median filter and Hybrid median filter.

A. Noise in Images:

Image noise [2] is the random variation of brightness or color information in images produced by the circuitry of imaging systems. The noise in an image is considered as a violation of the assumption of spatial coherence of the image intensities and is treated as an outlier random variable [3].
Image noise can also originate in film grain and in the unavoidable shot noise of an ideal photon detector. Image noise is generally regarded as an undesirable by-product of electronic image capture. Amplifier noise (Gaussian noise), Salt-and-pepper noise, Shot noise, Quantization noise (uniform noise), Film grain, Non-isotropic noise are some types in noise.

One of the most important families of nonlinear image filters is based on order statistics the widely used median filter is the best known filter of this family. Nonlinear filters based on order statistics have excellent robustness properties in the presence of impulsive noise. They tend to preserve edge information, which is very important to human perception. Their computation is relatively easy and fast compared with some linear filters. All these features make them very popular in the image processing community. Rank filters also called as Order statistics filters exhibit better performance as compared to linear filters when restoring images corrupted by impulse noise[7]. Impulse

noises are short duration noises which degrade an image. They may occur during image acquisition, due to switching, sensor temperature. They may also occur due to interference in the channel and due to atmospheric disturbances during image transmission. Order-static filters are nonlinear filters whose response is based on the ordering (ranking) the pixels contained in the image area encompassed by the filter, the value of the center pixel with the value determined by the ranking result.

B. Noise Calculation:

Noise is generally unwanted component in the image. $f(x, y)$ is the original image which distorted by noise sources is now $\hat{f}(x, y)$. Peak Signal to Noise Ratio

III. (PSNR)[5] IS GENERALLY USED TO ANALYZE QUALITY OF IMAGE, SOUND AND VIDEO FILES IN DB (DECIBELS). PSNR OF TWO IMAGES IS CALCULATED FROM ONE ORIGINAL AND AN ALTERED IMAGE(FILTERED IMAGE). HERE, MSE (MEAN SQUARED ERROR) IS FOUND FROM EXPECTATION OF DIFFERENCE FROM TWO IMAGES.

$$MSE = E(f - \hat{f})^2$$

$$PSNR = 10 \log_{10}\left(\frac{\max^2}{MSE}\right)$$

A lower value for MSE means lesser error, and as seen from the inverse relation between the MSE and PSNR, this translates to a high value of PSNR. Logically, a higher value of PSNR is good because it means that the ratio of Signal to Noise is higher. Here, the 'signal' is the original image, and the 'noise' is the error in reconstruction.

IV. MEDIAN FILTER

This filter [1, 3-4] replaces the centre pixel value by median gray levels in the neighbourhood of that pixel,

$\hat{g}(x,y) = \underset{(s,t)\in Sxy}{\text{median}}\{\hat{f}(s,t)\}$. Here $\hat{g}(x, y)$ is noisy image corrupted by noise. Median filters are particularly effective in the presence of impulse noise because of its appearance as white and black dots superimposed on an image. The problem with the median filter is, it removes both the noise and the fine detail since it can't tell the difference between the two. So, the median filter can't distinguish fine detail from noise.

V. ADAPTIVE MEDIAN FILTER

The Adaptive Median Filter [6],[1] performs spatial processing to preserve detail and smooth non-impulsive noise. The repeated applications of this Adaptive Median Filter do not erode away edges or other small structure in the image. It performs spatial processing to determine which pixels in an image have been affected by impulse noise. The Adaptive Median Filter classifies pixels as noise by comparing each pixel in the image to its surrounding neighbour pixels. The size of the neighbourhood is adjustable, as well as the threshold for the comparison. A pixel that is different from a majority of its neighbours, as well as being not structurally aligned with those pixels to which it is similar, is labelled as impulse noise. These noise pixels are then replaced by the median pixel value of the pixels in the neighbourhood that have passed the noise labelling test.

A. How Adaptive Median Filter Works?

Adaptive median filter [1] changes size of Sxy (the size of the neighborhood) during operation.

Zmin = minimum gray level value in Sxy
Zmax = maximum gray level value in Sxy
Zmed = median of gray levels in Sxy
Zxy = gray level at coordinates (x, y)
Smax = maximum allowed size of Sxy

B. Algorithm:

Level A: A1 = Zmed - Zmin
A2 = Zmed - Zmax
if A1 > 0 AND A2 < 0, go to level B
else increase the window size
if window size < Smax, repeat level A
else output Zxy
Level B: B1 = Zxy - Zmin
B2 = Zxy - Zmax
if B1 > 0 AND B2 < 0, output Zxy
else output Zmed

C. Explanation:

Level A:
IF Zmin < Zmed < Zmax, then
a. Zmed is not an impulse
i. go to level B to test if Zxy is an impulse ...
ELSE
b. Zmed is an impulse
i. the size of the window is increased and
ii. level A is repeated until ...
a) Zmed is not an impulse and go to level B or
b) Smax reached: output is Zxy
Level B: IF Zmin < Zxy < Zmax, then
a. Zxy is not an impulse
i. output is Zxy (distortion reduced)
ELSE
b. either Zxy = Zmin or Zxy = Zmax
i. output is Zmed (standard median filter)
a. Zmed is not an impulse (from level A)

Every time the algorithm outputs a value, the window Sxy is moved to the next location in the image. Then this algorithm is reinitialized and applied to the pixels in the new location on the spatial domain.

VI. HYBRID MEDIAN FILTER

Hybrid median filter (HMF) performs filtering[8] of the matrix A using a n x n box. An HMF preserves edges better than a square kernel median filter because it is a three-step ranking operation: data from different spatial directions are ranked separately. Three median values are calculated: MR is the median of horizontal and vertical R pixels, and MD is the median of diagonal D pixels. The filtered value is the median of the two median values and the central pixel C: median ([MR, MD, C]). As an example, for n = 5,

$$\begin{bmatrix} D & * & R & * & D \\ * & D & R & D & * \\ R & R & DCR & R & R \\ * & D & R & D & * \\ D & * & R & * & D \end{bmatrix}$$

Figure 1: Filter mask of Hybrid Median filter

VII. SIMULATION RESULTS

To test the performance of the above discussed Filtering algorithms, the following steps are executed on Matlab platform,

i. Uncorrupted image is taken as input.
ii. Noises are added to the image.
iii. The filtering algorithms are applied for reconstruction of images.
iv. Compute the PSNR values for different noise depth in image.

The above said steps repeated for mixed noise case also. These filtering techniques performed on 512x512 jpeg gray level image only. Simulation performed using Matlab 2009a version on Intel Pentium Dual core 3GHz processor, with 1GB RAM memory. Noise of Salt & Pepper with different noise probabilities.

In this simulation, test image is added with salt & pepper noise of noise probability of different values. Here images are shown for noise probability of 25%, corresponding filtering results from three rank filters.

Figure 2: Original Image

Figure 3: Image with salt & pepper noise of 25%

Figure 4: Median Filtered Image

Figure 5: AMF filtered Image

Figure 6: HMF filtered Image

A. Results for Noise of Salt & Pepper with combination of gaussian noise, Speckle noise:

The rank filters response is compared for mixed noise cases also. This random noise presence is in standard values only. Salt & pepper noise density is 25% with Gaussian noise of zero mean, variance of 0.01 and 0.1 values. Here the Matlab simulated results images are given for gaussian of variance of 0.01 values only. The resulting images shown, for mixed noises filtering is achieved with smoothening. Numerical results are tabulated below.

Figure 7: Image with salt &

Figure 8: Median Filtered pepper with gaussian noise

Figure 9: AMF filtered

Figure 10: HMF filtered

Table.1 For salt & pepper noise filters performance

PSNR (dB) Values for different noise density				
S.No	**Noise Probability (%)**	**Median Filter(dB)**	**AMF(dB)**	**HMF(dB)**
01	10	80.04	81.05	81.47
02	20	76.80	80.00	75.93
03	25	75.64	79.56	73.24
04	50	69.65	72.05	62.18
05	75	59.50	59.70	56.21
06	90	54.86	54.92	53.94

Filters performance drastically changes with respect to noise density present in image. For salt & pepper noise presence, above shown Table.1 gives the comparison results. Noise densities are varied from very low to maximum 90% value. Also, for more than single noise presence in an image case, here salt & pepper noise with Gaussian noise and salt & pepper noise with speckle noise combinations are considered. Image filtering also tested to get performance of above discussed filters performance. In table.2, the combination of both the salt & pepper noise, Gaussian noise types considered. This random noise presence is in standard values only. Salt & pepper noise density is 25% with Gaussian noise of zero mean, variance of 0.01 and 0.1 values. The resulting images shown, for mixed noises filtering is achieved with smoothening. Most

part of image information is smoothened with noises after filtering.

Table.2 Filter responses for image with both salt & pepper, Gaussian noises

PSNR (dB) Values for different noise density				
S.No	**Noise Variance**	**Median Filter(dB)**	**AMF(dB)**	**HMF(dB)**
1.	0.01	73.14	75.16	70.33
2.	0.1	67.15	67.75	63.69

For Gaussian noise only and speckle noise only filtering performance also estimated. These noises are simulated with standard values of variance only. These details are shown in table.3 below.

Table.3 Filter response for Gaussian noise only & Speckle noise only

Noise Type	**Median Filter(dB)**	**AMF(dB)**	**HMF(dB)**
Gaussian	67.92	67.89	67.93
Speckle	65.96	66.67	62.95

Here gaussian is generated with noise variance of 0.1 only and speckle noise of variance of 0.5 used. But using rank filters for these noise types won't give surety for edge preserving after filtering. Because smoothening makes lose of this edges and lines in the image.

VIII. CONCLUSION

In this paper, we discussed rank filters performance on two cases, .i.e. individual noise and mixed noise cases. In salt & pepper noise only case, in low noise density of salt & pepper noise condition, all rank filters give better results. But for more than 25% of salt & pepper noise density, median filter shows decaying performance prior to low noise density performance. In the same time, adaptive median filter outperforms remaining two filters. The interesting thing in these filter group is, the adaptive filter. It performs equally well in low and very high noise density conditions with median filter. Also gives better result for moderate noise density values. We can infer this from table.1. Also Hybrid median filter is very close to median filter. It has no significant performance in high noise density conditions. But adaptive filter circumvents this problem and performs in better way on comparing with others. It is evident to consider denoising using only adaptive median filter to high noise density of salt & pepper noise affected images. For gaussian noise removal, three filters perform well, but smoothening is more, which deteriorates image information. In the second case, i.e. in mixed noise cases, for salt & pepper noise with gaussian noise mixed condition, adaptive filter does the good job. For speckle (multiplicative type) noise, median and adaptive filters are very close in their performance marginally. To study further on this paper, it may be recommended to use FPGA [9] platform for getting accurate and specific hardware based performance of filters.

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