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Impulse Noise Removal and Detail-Preservation in Images and Videos Using Improved Non-Linear Filters

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Abstract: *Though many ramification of Linear Signal Processing are studied and worked on, but due to the inevitable effects of non linearities present during signal generation or within the systems, one has to look beyond the linearity and reach into nonlinear signal processing ventures. Human Visual System and image capturing devices are both nonlinear. Hence nonlinear filtering methods outperform its linear counterpart in many applications. Linear methods are unable to remove impulsive noise in images by preserving its edges and fine details. In addition, linear algorithms are unable to remove signal dependent or multiplicative noise in images. This paper presents an approach to denoise and smoothen the impulse noised color images and videos using improved Kuwahara and SNN filter. It involves a two stage algorithm which includes a noise detection followed by filtering. Numerous experimental results demonstrate that proposed method outperforms the existing method by eliminating the painting like flattening and blurring artifact along the local feature direction while preserving edge and betterment in image representation with improvement in PSNR and MSE*.

Keywords: *Kuwahara, SNN, PSNR, MSE.*

1. INTRODUCTION

Digital Image Processing focuses on two major tasks: Improvement of pictorial information for human interpretation; Processing of image data for transmission and representation for autonomous machine perception. Image processing involves transformation which takes an image into an image, i.e. it starts with an image and produces a modified (enhanced) image. The continuum from image processing to computer vision can be broken up into low-, mid- and high level processes which involves noise removal, image sharpening, object recognition, segmentation, scene understanding and autonomous navigation. [7]. Filtering is the most fundamental operation of image processing and computer vision. In the broad cast sense of the term 'filtering',the value of filtered image at a location is a function of the values of the input image in a small neighborhood of the same location. Images and videos are often contaminated by impulse noise during transmission through communication channel or during acquiring the image. It is important to eliminate noise in images before subsequent processing such as edge detection, image segmentation and object recognition. Although many methods have appeared in scientific literature, each has its own advantages and limitations. The performance of impulse noise (salt and pepper noise) normally increases with the complexity of the implemented algorithm. On other hand methods with low complexity filters impulse noise at the expense of image details and textures. Moreover some methods require laborious calculations and timing of parameters used in the filtering algorithm. Specifically for removal of salt and pepper noise several nonlinear filters have been proposed. The Median Filter and its variants was the most popular nonlinear filter for removing impulse noise because of its good denoising power and computational efficiency [1]-[4]. However at high noise densities some details and edges of the original image are smeared by the filter. Later on different adaptive median filters has been proposed to restore the impulse corrupted by high density impulse noise.

In conventional nonlinear filtering methods using Kuwahara[5] and SNN[9], filtering operations are performed to each pixel unconditionally without considering whether a pixel is corrupted or un corrupted which would inevitable alter the pixel values and remove signal detail of un corrupted pixel. Various improvement has been made to basic nonlinear filters to improve its performance on noisy images .One such improvement is filtering after noise detection which is proposed in this paper. Filtering is done after noise detection on the detected noisy pixel by nonlinear filter and extended the same to video frames.

2. NOISE MODEL AND DETECTION ALGORITHM

2.1 Impulse Noise Model

Images may be contaminated by various sorts of noises.

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The type of noise considered by our proposed algorithm is bipolar impulse noise or salt and pepper noise or fixed valued impulse noise whose value is generally independent of the strength of the image signal. The PDF of bipolar impulse noise is given by (1)

$$p(x) = \begin{cases} P_a & for\ x = a \\ P_b & for\ x = b \\ 0 & otherwise \end{cases} \quad (1)$$

If b>a, intensity b will appear as a light dot in the image. Conversely, level a will appear like a dark dot. [7]

Noise impulses can be negative or positive. It will take a gray level vale of minimum or maximum in the dynamic range.Positive impulses appear as black (pepper) in an image and Negative impulses appear as white (salt) noise.

2.2 Noise Detection Algorithm

Various noise detection techniques have been proposed for detection of impulse noise. In the proposed algorithm, noise detection is done through thresholding.The threshold (T) is user defined value between the minimum and maximum value in the gray level of noisy image which is used to distinguish an informative pixel from a noisy pixel. The various steps involved in detecting noisy pixels

- Check for pixels with values 0 and 255, which are considered possibly to be noisy pixels for 8-bit monochrome images and video frames.
- For each such pixel consider a 3x3 neighborhood around the pixel.
- Find the arithmetic mean of absolute difference between the identified signal and its neighborhood.
- The arithmetic mean (AM) is then compared with the user defined threshold set to check if signal is noisy or informative.

1. If AM $\geq$ T, the pixel is noisy.
2. If AM $\leq$ T, the pixel is informative.

When the pixel is found to be near borders of image ,the value of pixels are considered as a non-zero value obtained by taking the mean of corner pixels of neighborhood instead of assuming it to be zero.[10]

3. NON LINEAR FILTERS

3.1 Kuwahara Filter

The Kuwahara filter is a non-linear smoothing filter used in image/video frame processing for adaptive noise reduction. It works by calculating the mean and variance for four sub region as shown in Figure 1. [9]

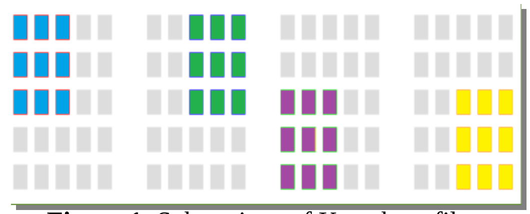


Figure 1: Sub regions of Kuwahara filter

The arithmetic mean m(x,y) and standard deviation σ(x,y) of the four regions centered around a pixel(x, y) are calculated and used to determine the value of the central pixel. The output of the kuwahara filter is given as

$$\theta(x,y) = \begin{cases} m_1(x,y)\ if\ \sigma_1(x,y) = min_i\,\sigma_i(x,y) \\ m_2(x,y)\ if\ \sigma_2(x,y) = min_i\,\sigma_i(x,y) \\ m_3(x,y)\ if\ \sigma_3(x,y) = min_i\,\sigma_i(x,y) \\ m_4(x,y)\ if\ \sigma_4(x,y) = min_i\,\sigma_i(x,y) \end{cases} \quad (2)$$

It means that the central pixel will take the mean value of the area that is most homogenous.Eventhough it smoothens the image but creates a painting like flattening effect along the local features and sharp edges are also blurred. [6]

3.2 Symmetric Nearest Neighbor Filter

The SNN [9] smoothing and anisotropic nonlinear 2D filter is a noise reducing and edge preserving filter that blurs the image while preserving the edges. It is a filter related to the mean and median filter. The neighbors of the central pixel in a window are considered as four pairs of symmetric pixels. For each pair the closest to the central pixel is selected. The four selected pixels are averaged and the mean value is replaced for central pixel as shown in Figure 2. [8]

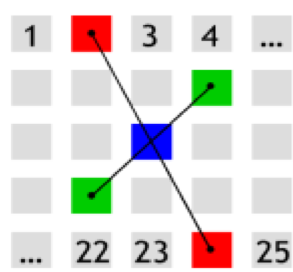


Figure 2: Symmetric Opposite Pixel pairs in SNN Filter

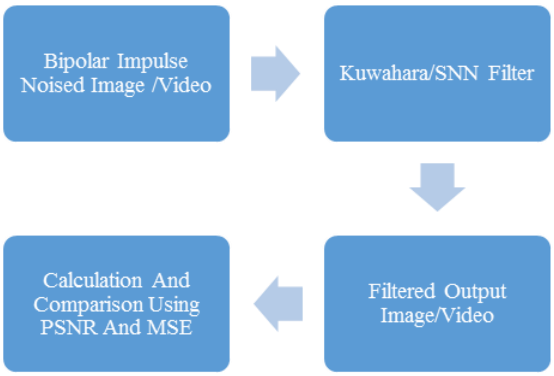
3.3 The Proposed Improved Non Linear Filter

The Improved Kuwahara and SNN Filter involve noise detection followed by filtering as shown in Block diagram 4.2. Instead of applying filter to the whole image /video frame pixels, noisy pixels are identified using noise detection algorithm mentioned in heading 2 and filter is applied only to noisy pixel. For Improved Kuwahara Filter the edges are preserved and the painting like flattening effects is removed. For

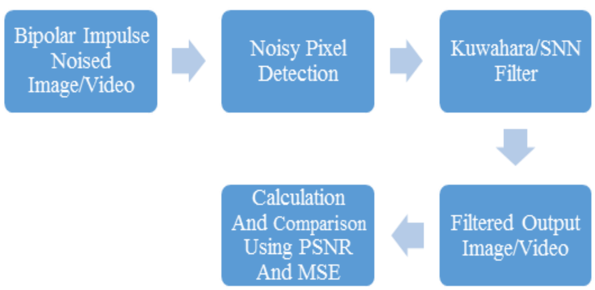
Improved SNN filter there is betterment in appearance by removal of noise blotches and blurring effect is reduced. There is increase in PSNR compared to the conventional one for both the methods.

4. BLOCK DIAGRAM

4.1 Conventional Noise Removal Using Non Linear Filter



4.2 The Proposed Improved Non Linear Filter



5. SIMULATION RESULTS

Among the commonly tested 256-by-256 8-bit color image the one with homogenous region (Lena) and video frame (traffic) were analyzed for different noise density of Bipolar Impulse Noise [4].The parameters used to define the performance of the proposed filter are :

1. PSNR (Peak Signal to Noise Ratio): It is the ratio between the maximum power of signal and the power of corrupting noise that affects the fidelity of representing images/frames.

$$PSNR = 20\log_{10}\left(\frac{255^2}{MSE}\right) \quad (3)$$

2. MSE (Mean Square Error): It is the average squared difference between reference I(x,y) and distorted image /video frame I^ (x,y).

$$MSE = \frac{1}{MN}\sum_{i,j=1}^{M,N}[I(i,j) - \hat{I}(x,y)] \quad (4)$$

The Results of Conventional and Proposed Improved nonlinear filters for a noisy image with noise density 0.2 are shown in Figure 3 and Figure 4


(a)


(b)

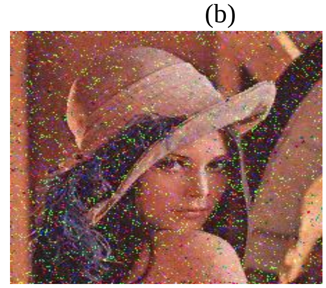

(c)

Figure 3: (a) Noisy Image (n=0.2) (b) and (c) Pictorial results for Conventional and Improved Kuwahara Filter on Color Lena Image


(a)


(b)

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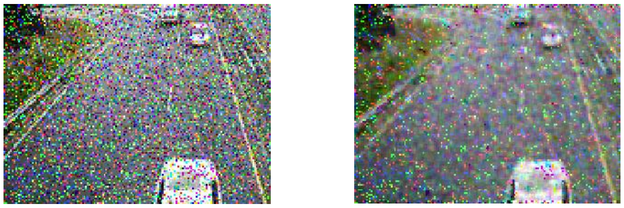
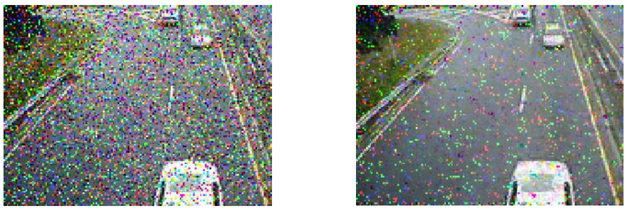
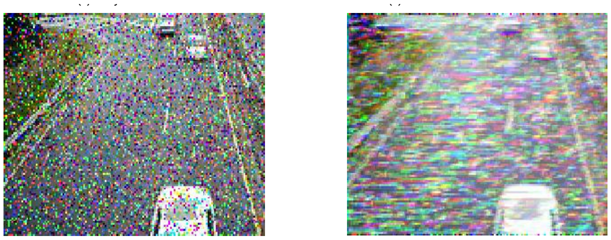


(c)



(d)



(e)

(f)

Figure 4: (a) and (b) Pictorial results for Conventional and Improved SNN Filter on Lena color image (Noise Density=0.3). (c) and (d) Pictorial results for Conventional and Improved Kuwahara Filter on traffic video frame (Noise Density=0.3). (e) and (f) Pictorial results for Conventional and Improved SNN Filter on traffic video frame (Noise Density=0.3).

Table 1: Quantitative Analysis of Conventional and Improved Kuwahara Filter Output for Bipolar Impulse Noise on color Lena Image

Noise Density (%)	**Conventional Kuwahara**		**Improved Kuwahara**	
	MSE	**PSNR (dB)**	**MSE**	**PSNR (dB)**
0.2	0.019	65.46	0.009	68.31
0.4	0.029	63.55	0.017	65.75
0.6	0.161	56.06	0.073	59.58
0.8	0.345	52.75	0.215	54.80

Table 2: Quantitative Analysis of Conventional and Improved SNN Filter Output for Bipolar Impulse Noise on color Lena Image

Noise Density (%)	**Conventional SNN**		**Improved SNN**	
	MSE	**PSNR (dB)**	**MSE**	**PSNR (dB)**
0.2	0.064	60.09	0.012	67.43
0.4	0.111	57.69	0.043	61.83
0.6	0.173	55.76	0.102	58.04
0.8	0.263	52.93	0.209	54.91

From Table 1 and Table 2, the result of PSNR and MSE is better in Improved Kuwahara and SNN Filter than Conventional.

6. CONCLUSION

An Efficient noise removal and Edge Detail-Preservation in color images and videos are obtained by the proposed Improved Kuwahara and SNN Filter which is clearly evident from Figure 3 and Figure 4. The Quantitative analysis result manifest the superiority of the Improved Nonlinear filters in PSNR and MSE performance and is very efficient with its computational time.

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