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Improved Kuwahara Filter for Bipolar Impulse Noise Removal and Edge Preservation in Color Images and Videos

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***Abstract*—Both image capturing devices and human visual systems are nonlinear. Hence nonlinear filtering methods outperforms 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 Bipolar impulse noised images and videos using improved Kuwahara filter .It involves a two stage algorithm which includes a noise detection followed by filtering . Numerous simulation demonstrate that proposed method outperforms the existing method by eliminating the painting like flattening effect along the local feature direction while preserving edge with improvement in PSNR and MSE.**

Keywords—Bipolar Impulse noise ,Kuwahara,PSNR MSE,PDF

I. INTRODUCTION

As one picture is worth more than a thousand words, so interest in digital image processing methods stem from two principal application areas: improvement of pictorial information for human interpretation; and processing of image data for storage, transmission and representation for autonomous machine perception. [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 a bipolar impulse noise (salt and pepper noise) normally increases with the complexity of the implemented algorithm. On other hand methods with low complexity filters bipolar impulse noise at the expense of image details and textures. Moreover some methods requires laborious calculations and timing of parameters used in the filtering algorithm.[5]

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[6], 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 those un corrupted pixel. Various improvement has been made to basic nonlinear filter to improve its performance on noisy images .One such improvement is filtering after noise detection 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.

II. NOISE MODEL AND DETECTION ALGORITHM

A. Impulse Noise model

Images may be contaminated by various sorts of noises. 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

$$P(x) = \begin{cases} P_a \ for\ x = a \\ P_b \ for\ x = b \\ 0 \ otherwise \end{cases}$$

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 value of minimum or maximum in the dynamic range. Negative impulses appear as black (pepper) in an image and Negative impulses appear as white (salt) noise.

B. 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 ≥ T, the pixel is noisy.
2. If AM ≤ 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.[9]

III. NON LINEAR FILTER

A. 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 Fig 1.[8]

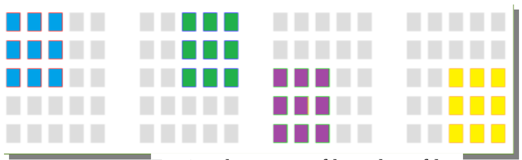


Fig 1: sub regions of kuwahara filter

The arithmetic mean $m_i(x, y)$ and standard deviation $\sigma_i(x, y)$ 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

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

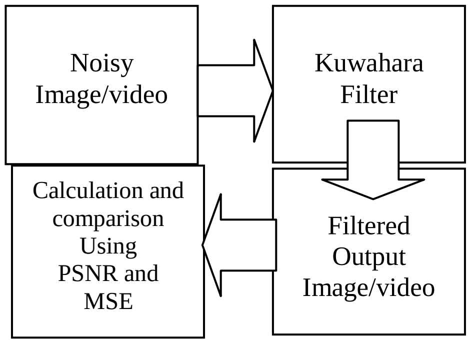
It means that the central pixel will take the mean value of the area that is most homogenous.Eventhough it smoothens the image but creates a painting like flattening effect along the local features and sharp edges are also blurred.[6]

B. The Proposed Improved Kuwahara Filter

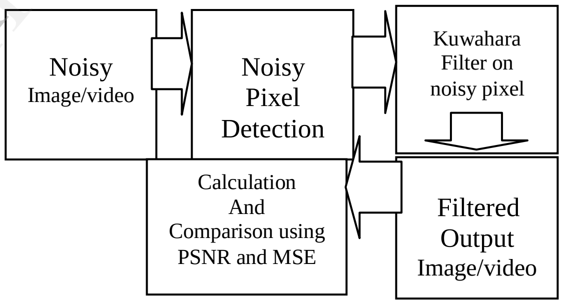
The Improved Kuwahara Filter involves noise detection followed by filtering as shown in Block diagram IV B. Instead of applying filter to the whole image /video frame pixels, noisy pixels are identified using noise detection algorithm mentioned in heading II and filter is applied only to noisy pixel. The edges are preserved and the painting like flattening effects are removed. There is increase in PSNR compared to the conventional one.

IV. BLOCK DIAGRAM

A. Conventional Noise Removal using Kuwahara Filter.



B. The Proposed Improved Kuwahara filter



V. 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 [2].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.

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

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

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

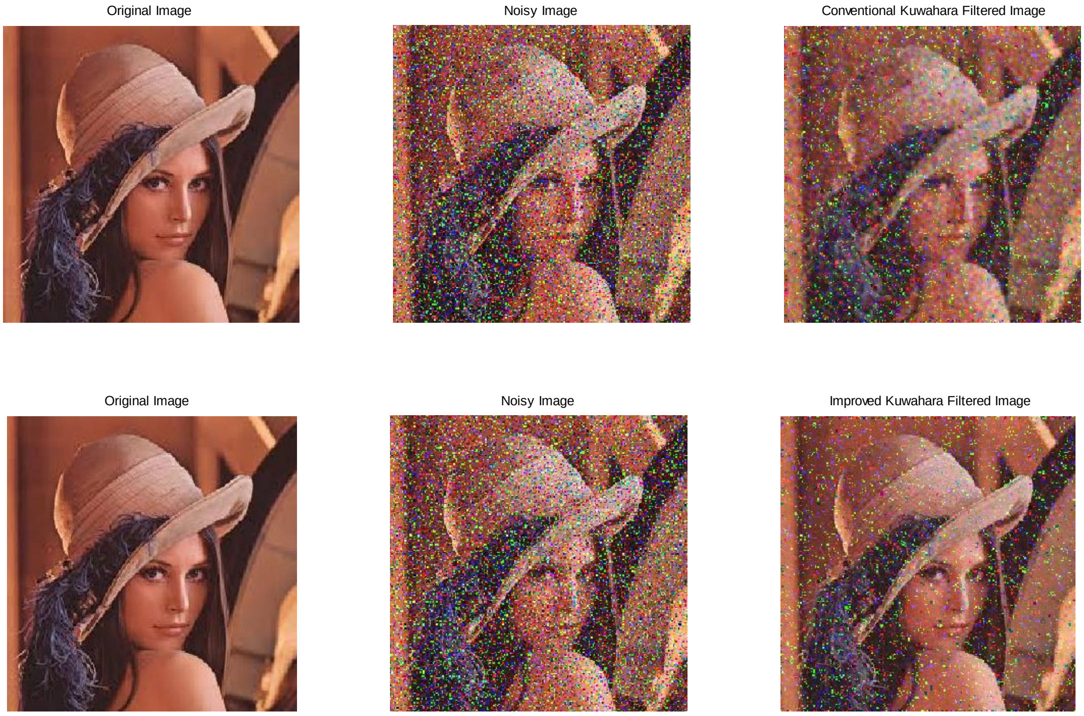


Fig2: Pictorial results for Conventional and Improved Kuwahara Filter on color Lena image (Noise Density =0.3)

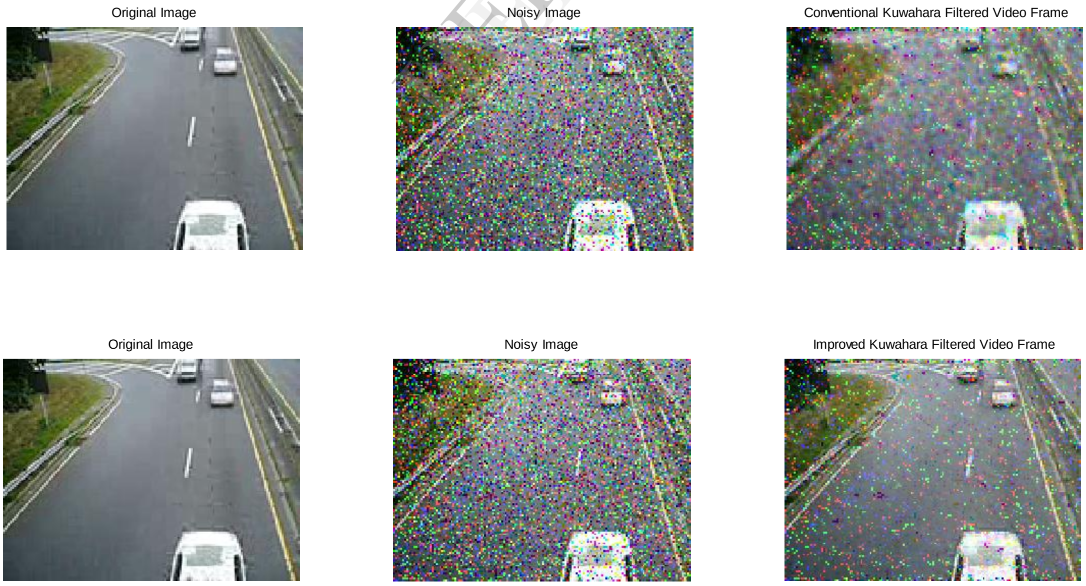


Fig3: Pictorial results for Conventional and Improved Kuwahara Filter on traffic video frame (Noise Density =0.3)

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	0.0185	65.4590	0.0096	68.3080
0.4	0.0287	63.5519	0.0173	65.7503
0.6	0.1611	56.0595	0.0725	59.5809
0.8	0.3452	52.7475	0.2152	54.8032

As shown in table 1, the result of PSNR and MSE is better in Improved Kuwahara Filter than Conventional.

VI. CONCLUSION

An intelligent noise removal and edge preservation in color images and video is obtained by the proposed improved Kuwahara Filter which is clearly evident from Fig 2 and 3. The Quantitative analysis results manifest the superiority of the improved Kuwahara filter in PSNR and MSE performance and is very efficient with its computational time

VII. ACKNOWLEDGEMENT

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