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Sharpness Estimation and Denoising of Images Using Adaptive Bilateral Filter and Its Comparison with Various Filtering Methods

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Abstract- Image restoration basically refers to recover a high quality original image from a degraded version of that image. Image denoising is one of the most important tasks in image processing, analysis and image processing applications. The images are affected by Gaussian Noise for our observations. In this paper, we have obtained adaptive bilateral filtered image and compared it with results of Butterworth filter, and Median filter. Different image filtering methods are compared using the Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE). The Adaptive Bilateral Filter gives desirable results in terms of the above parameters.

Index Terms- Median filter; Adaptive Bilateral filter; noise removal; Mean Square Error; PSNR.

1. INTRODUCTION

In everyday life, digital images processing have many applications it includes digital cameras, intelligent traffic monitoring, handwriting recognition on checks, signature validation and so on. However, it is not uncommon that images are contaminated by noise due to several unavoidable reasons. Poor image sensors, imperfect instruments, problems with data acquisition process, transmission errors and interfering natural phenomenon are its main sources. Therefore, it is necessary to detect and remove noises present in the images. Reserving the sharpness of an image and removing the random noise as far as possible is the goal of image restoration approaches.
An image may be contaminated by noise in its transmission or acquisition. Noise is any unwanted information that corrupts an image. There are many different types of noise which can be classified into Gaussian noise, speckle noise and salt & pepper noise.

2. METHODS OF FILTERING

Filters are the electronic circuits which have the functionality to remove the unwanted noise components from the images. In the field of the digital image processing, filters have the numerous applications.

2.1. *Adaptive Bilateral Filtering*

Traditional filtering is domain filtering and enforces closeness by weighing pixel values with coefficients that are near in distance with center pixel. The bilateral filter proposed by Tomasi and Manduchi [1] in 1998 is a nonlinear filter that smoothes the noise while preserving edge structures. The bilateral filter is a non linear filter and it provides an effective image denoising. By combining two Gaussian filters which one filter applies in spatial domain and the other one works in intensity domain that achieves spatial weighted averaging without smoothing edges. After segmentation, the image quality can be improved by using the bilateral filter. The shift-variant filtering operation of the bilateral filter is given by

$$f[m,n] = \sum_k \sum_l h[m,n;k,l]\,g[k,l] \qquad (1)$$

where, $\hat{f}[m,n]$ is the restored image, $h[m,n;k,l]$ is the response at $[m,n]$ to an impulse $[k,l]$ and $g[m,n]$ is the degraded image. Normalization factor is given by

$$r\,m_0,n_0 = \sum_{m=m_0-N}^{m_0+N} \sum_{n=n_0-N}^{n_0+N} \exp(-(m-m_0)^2 + (n-n_0)^2 | 2\sigma_d^2) \times \exp(-(g[m,n] - g[m_0,n_0])^2 | 2\sigma_r^2) \qquad (2)$$

where, $[m_0\, n_0]$ is the centre pixel of the window. σd and σr are the standard deviations of the domain and range Gaussian filters, respectively.

2.2. *Median Filtering*

Median in statistics means the value in middle. Median filter is popular in removing salt & pepper noise and works by replacing the pixel value by the median value in the neighborhood of that pixel. For color images Since each pixel is RGB here we don't use brightness but we compare each pixels color of every other in the neighborhood. The pixel whose red, green, and blue components have the smallest sum of squared differences from the color coordinates of its neighbors is then chosen to replace the central pixel of the neighborhood.

$$g[k,l] = \text{median}\{x[i,j], (i,j) \in w\} \quad (3)$$

The neighborhood w can be represented on location (k,1)in the image. The median filter selects the middle value of pixel (x,y).For an NxN window W(x,y) with pixel (x,y) and the midpoint of W, the intensity values of pixels in W are ordered from smallest to the largest.

2.3. *Butterworth Filtering*

Butterworth filter is characterized by the property and its magnitude response is flat in both pass-band and stop-band. The magnitude squared response of an N-order low-pass filter. It does not have sharp discontinuity and no clear cut-off between passed & filtered frequencies. The squared response of the Butterworth filter is given as the function of the cut-off frequency.

$$|H(j\omega)| = \frac{1}{\sqrt{1 + (\omega / \omega_c)^{2n}}} \quad (4)$$

Where Ω_c is the cutoff frequency in rad /sec.

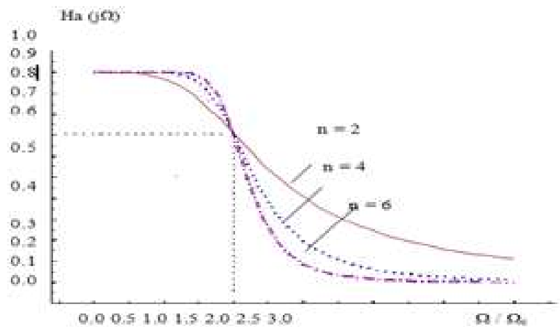

Fig. 1 Frequency response of Butterworth Filter

Butterworth filters have a monotonically changing magnitude function with ω, unlike other filter types that have non-monotonic ripple in the pass band and/or the stop band.

2.3.1Properties of Butterworth Filter

- The Magnitude response is,
  - $|H_a(0)|^2 = 1$, $|H_a(j\Omega_c)|^2 = 0.5$, for all N at Ω_c 3dB attenuation.
  - $|H_a(j\Omega)|^2$ monotonically decrease for Ω
  - Approaches to ideal filter when $N \to \infty$

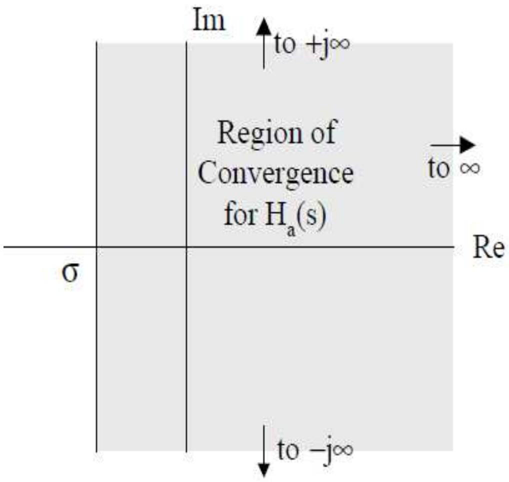

Fig. 2 Region of convergence for the transfer function of the filter.

3. EXPERIMENTAL RESULTS AND DISCUSSION

All three filtering methods were tested on several images with added Gaussian white noise. Butterworth and median filtering methods were compared to the Adaptive Bilateral Filtering method using three different criteria such as visual quality, mean square error (MSE) and peak signal to noise ratio (PSNR) comparison. When compared visually, the denoised images obtained using the bilateral filtering method were clear and did not seem to contain any noise. The smaller MSE value and the larger PSNR value determine which filter is the best performance on image denoising.

Table 1: PSNR and MSE values for Gaussian noise

	PSNR	MSE
Noisy image	51.5536	0.4547
Median filter	71.0434	0.0151
Butterworth filter	71.3608	0.0081
Adaptive Bilateral filter	73.7145	0.0014

3.1 Visual Quality

Visual Quality Comparison between various noises which used to preserve the edge detection. For example, Gaussian noise added to the image and bilateral filtering image give an assure to visual quality when compared to other image denoising techniques. It was able to recover minute details of the original image and lightly successful way of approaching image denoising.

Fig. 3 Noisy input image with Gaussian noise

Fig. 4 Butterworth filtered image

Fig. 5 Median filtered image

Fig. 6 Adaptive bilateral filtered image

4. CONCLUSION

On the analysis of the test results, the Adaptive bilateral filter proved to be the better method for image denoising and enhancing the sharpness at the edges. The Butterworth and median filtering method performed poorly on the test cases. However, the denoised images still showed significant amount of noise in case of median filtering and butterworth filtering. The adaptive bilateral filter managed to perform better than other filters in Gaussian white noise. The adaptive bilateral filter showed the lowest values of MSE and higher PSNR as compared to other techniques. The Butterworth filter failed to remove noise in this case whereas median filter was better than Butterworth in performance. It was able to recover more details of the original image and successfully approached to be a good image denoising method. The proposed denoising technique has effectively removed the AWGN noise from the images and improved the quality of the images. The denoising has been performed well by the proposed technique and also it has offered a good PSNR for the denoised images. The performance has been well illustrated by comparing the PSNR of the noisy images and the denoised images.

5. FUTURE SCOPE

For future scope of this paper , we would suggest that the following issues be addressed. First, the ABF tends to posterize the image, due to its basic mechanism of sharpening an image by pulling up or pushing down pixels along the edge slope. Second, the ABF does not perform as well at corners as it does on lines and spatially slow-varying curves, since the ABF is primarily based on transforming the histogram of the local data, which cannot effectively represent 2-D structures.

Finally, in the current design of the ABF, a fixed domain Gaussian filter is used. We can also experiment with different normalization techniques and also by jointly optimizing both the domain and the range filters.

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