*International Conference on Recent Advances in Communication, VLSI & Embedded Systems*
*ISSN (Online):2349-0020, ISSN (Print): 2394-4544, (ICRACVES-2014)*

# Analysis of Adaptive Bilateral Filtered Images

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*Abstract*— **In this paper, implementation of an image filter algorithm (Adaptive Bilateral Filter) is shown, whose aim is to recover a quality image from a noisy image and calculate the quality of the image. The image quality can be improved by de-nosing. Image noise removal is an important image processing task in digital image processing. This can be implemented on Gray images, colour and text images.**

***Keywords*— Bilateral filter, Noise removal, Image quality, Gray images, Color images, Text images, Psnr.**

## I. Introduction

In signal processing, filter is a device which removes unwanted signals like random noise, or to extract some part of signal with in a specific frequency range. Filters are classified into, analog filters and digital filters. An analog filter uses analog electronic circuits made up from components like resistors, capacitors and operational amplifiers to produce the required filtered output. Such filters are widely used in such applications as noise filters, video signal filters, equalizers in high-fidelity systems etc,. digital filter performs operations on sampled values of the signal on a processor. The analog signals are sampled and given as input to analog to digital convertor(ADC),which converts the analog signals to digital binary digits, which are given as input to the processor and it performs various operations. If the binary digits are necessary to convert back to analog samples, these can be given to digital to analog convertor(DAC).

Digital Image processing can be implemented by digital filters which include smoothing, improving the edge slope, and sharpening. Filtering can be classified into non linear and linear filtering. Linear filtering is a technique used for enhancing and modifying an image. Linear filtering is based on pixel neighborhood operation with respect to the selected input pixel. Linear filters are capable of removing noise. Non linear filters are extended linear filters which are based on order statistics, and are very faster than linear filters because they only perform comparisons. Image enhancement is a process, which is used to improve noisy or blur images in order to have a better look. The main objective of enhancement is to process an image and obtain a suitable image than the original one. It can be performed by Spatial Domain(pixel manipulation) and frequency domain (modifying Fourier transform).

Image enhancement techniques can be perform on an image for Brightness adjustment, contrast adjustment, modifying the size, inversion, conversion, correction, color balancing, sharpening, format conversion, and blurring. A process which aims to invert known degradation operations applied to images. Image restoration methods are used to improve the appearance of an image by applications of a restoration process that uses a mathematical model for image degradation.

## II. Bilateral filter

Bilateral filtering is a non-linear filtering technique which extends the Gaussian smoothing concept by weighting the filter coefficients with their relative pixel values. The Pixels which have different intensity, when compared from the central pixel are weighted less even though they have very close proximity to the central pixel. The edge-preserving de-noising bilateral filter uses a low pass Gaussian filter for both the domain filter and the range filter. The domain filter gives higher weight to pixels that are spatially close to the center pixel. The range filter gives higher weight to pixels that are similar to the center pixel in gray value. By using the range filter and the domain filter, a bilateral filter ensures that averaging is done mostly along the edge and is greatly reduced in the gradient direction. This makes the bilateral filter perform smoothing the noise while preserving edge structures. The shift-variant filtering operation of the bilateral filter is given by the equation (1).

$$f'(m,n) = \sum_{k} \sum_{t} h\,[m,n;k,l]\; g[k,l] \quad \ldots\ldots \quad (1)$$

Where f^ [m, n] is the restored image, h [m, n; k, l] is the response at to an impulse at, and g[m, n] is the degraded image. The bilateral filter equation can be as equation (2).

$$Ifiltered\,(x) = \frac{1}{Wp} \sum_{Xi \in \Omega} I(Xi)\, fr(\|I\;(xiI(x)\,\|)\, gs\;(\|xi - x\|)) \quad \ldots\ldots \quad (2)$$

The normalization term can be given by the equation (3) as shown below.

$$Wp = \sum_{xi \in \Omega} fr\,(||I\,(xi) - I(x)\,||)\; gs\,(||xi - x) \quad \text{.....(3)}$$

Where (I filtered) is the filtered image. (I) is the original input image to be filtered. x is the coordinates of the current pixel to be filtered. Ω is the window centered in x.fr is the range kernel for smoothing differences in intensities.gs is the spatial kernel for smoothing differences in coordinates. As mentioned above in the equation (3), the weight Wp is assigned using the spatial closeness and the intensity difference. Consider a pixel located at (i, j) which needs to be de-noised in image using its neighboring pixels and one of its neighboring pixels is located at (k, l). Then, the weight assigned for pixel (k, l) to de-noise the pixel (i, j) is given by the equation (4).

$$W\,(i,j,k,l) = e \quad \frac{(i-k)^2 + (j-l)^2}{(2\sigma r)^2} - \frac{||I\,(i,j) - I\,(k,l)||}{(2\sigma r)^2} \quad \text{.... (4)}$$

Where $\sigma_d$ and $\sigma_r$ are smoothing parameters and I (i, j) and I (k, l) are the intensity of pixels (i, j) and (k, l) respectively. Calculate the weights, normalize them.

$$ID\,(i,j) = \frac{\sum kl\; I(k,l) * W\,(i,j,k,l)}{\sum kl\;\; W\,(i,j,k,l)}$$

...(5)

Where, ID is the de-noised intensity of pixel (i, j).

## III. ADAPTIVE BILATERAL FILTER

The adaptive bilateral filter (ABF) uses a new sharpening and smoothing algorithm. The ABF retains the general form of a bilateral filter, but contains two modifications. First, an offset is introduced in the range filter in the ABF and second, both and the width of the range filter in the ABF are locally adaptive and changeable. If it is fixed, the ABF will degenerate into a conventional normal bilateral filter. A fixed domain filters which is adopted in the ABF. The combination of a locally adaptive and transforms the bilateral filter into a much more powerful filter that is capable of both smoothing and sharpening.

The advantage of defining the filter in this manner is that it allows non-linear filtering that allows both spatial and amplitudinal locality at the same time. The amplitude at a point is considered by neighboring points with similar amplitudes more than by those with other different amplitudes. This results in reduced smoothing across signal regions by large but consistence variances in amplitude, thus better preserving of such signal. It will produce undesirable results in situations where the signal to noise ratio is low. In situations where the signal to noise ratio is low, amplitudinal differences between neighboring points are often large even in the smoother regions of the signal. To achieve noise suppression in smooth regions in such a situation, the spatial spread and amplitudinal spread must be made sufficiently large to accommodate for the increased variation. However, such a large spread can have the adverse effect of over-smoothing the signal in regions of significant signal detail. To alleviate this problem, we propose the adaptation of these constraint parameters based on the perceptual sensitivity of the human perception system to the underlying signal characteristics.

Where [m0, n0] and **Ω**m0**,** n0 are defined as before, and the normalization factor is given by the equation (6).

$$m0, n0 = \sum_{m=m0-N}^{m0+N} \sum_{n=n0-N}^{n0+N} \exp \frac{-(m-m0)x^2 + (n-no)^2}{(2\sigma d)^2} \quad X\, exp - \frac{(\;(g\,[m,n] - g\,[m0,n0] - \zeta\,[m0,n0)\;\;^2}{(2\sigma r)^2 [m0,n0]}$$

.... (6)

### *A. Degradation model*

Images are the useful information which can be recordable and saved in the storage. Improper capturing of an image results in degraded images. There are many kinds of distortions. The different degradations consider noise, pin cushion distortion, illumination and color imperfections, and blurriness of the image.

General model,

$$G\,(x,y) = T\,(f(x,y)) + n(x,y) \quad \text{.... (7)}$$

T(x, y) may not be linear, Modeling T (x, y) by a filtering operation.

$$G\,(x,y) = f(x,y) * h(x,y) + n(x,y) \quad \text{... (8)}$$

The degradation operator is linear and shift invariant, h(x, y) is unknown and needs to be estimated which given in the equation (8).

### *B. Noise types*

Noise is any undesired information that contaminates an image. Noise appears in images from a variety of sources. In typical images the noise can be modeled with a Gaussian ("normal"), uniform, or salt-and-pepper ("impulse") distribution. The blurriness is a noise present in an image, can be caused by many factors like Movement during the image capture process or by the camera or when long exposure times are used, Out-focus, by using wideangle lens, atmospheric noise, or a short exposure time.

The value of a pixel should be the light intensity at a infinitesimal point in the imaged Scene. Each sensor in a CCD array integrates the light intensity in a small area surrounding a point with possibly non-equal weighting. The point spread function (PSF) is the image captured when there is only one single point with High intensity in the scene. This PSF is the degradation filter. Typically h(x, y) due to sensor PSF is low-pass and is often approximated by a Gaussian filter's equation (9).

$$\mathrm{H(x,y)} = e^{-k}(x^2 + y^2) \qquad \ldots(9)$$

TABLE .I PSNR VALUES

| Image type | Adaptive Bilateral Filter(ps |
|---|---|
| Gray image (d) | 75.79 |
| Colour image (h) | 74.51 |
| Text image (m) | 84.40 |

*C. Mean square error*

The mean-square-error (MSE) is given by the equation

$$\mathrm{MSE}(f, f') = \mathrm{f(x)} f\hat{}(x)^2 . dx \qquad \ldots (10)$$

Where f' is the original image, and f` the restored image. The mean-square-error measures the difference in energy between the compared images. The MSE can be calculated both in the spatial domain and in the frequency domain as given in equation (10).

*D. Peak-signal-to-noise-ratio(psnr)*

PSNR is used to measure the quality of reconstruction of noisy image. PSNR is an approximation to human perception of reconstruction quality.

## IV. RESULTS

The below table (1) shows the experimental results which are obtained for the images filtered by adaptive bilateral filter i.e., the peak-signal- to- noise-ratio(PSNR) obtained by the adaptive bilateral filter for gray image, color image, text image.

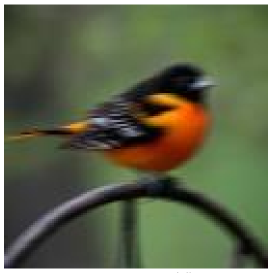

(1)

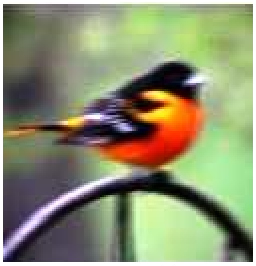

(2)


(3)

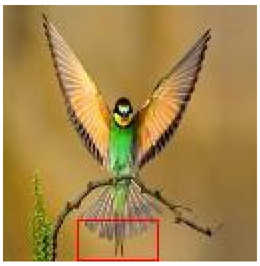

(4)


(5)


(6)

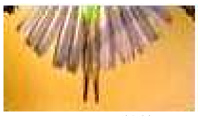

(7)

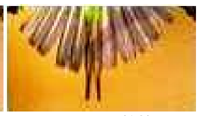

(8)


(9)


(10)


(11)


(12)


(13)


(14)


(15)


(16)


( 17)

Figure.1. (1) Gray Image (2) Noisy image (3) Bilateral filtered Image (4) Adaptive bilateral filtered image (5) Color image (6) Noisy Image (7) Bilateral filtered Image (8) ABF color image (9) Region of Interest 10) selected region 11) Region Degraded 12) BF Region 13) ABF region (14) Text Image (15) Noisy Text (16) Bilateral filtered Text (17) ABF Text

From the above results, we can observe that figure 1.(1) is the original gray image, which is given as input image and figure 1.(2) is the distorted image, after adding noise. When the distorted image is filtered (passed) through bilateral filter, the filter smoothes the image as shown in the figure 1.(3), where as the image passed through the adaptive bilateral filter, it smoothes the image and sharpens the image as shown in the figure 1.(4).Similarly in the case of colour images as shown in figure 1.(5), 1.(6), 1.(7), 1.(8).

In figure 1.(9), a specific region or part of an image is selected and implemented both bilateral and adaptive bilateral filters and obtained the results as shown in figure 1.(10),1. (11), 1.(12), 1.(13).the out puts of text images are obtained as shown in figure 1.(14), 1.(15), 1.(16), 1.(17).

## V. CONCLUSION

The image enhancement and de-noising of gray and colour images using bilateral and adaptive bilateral filter is implemented and achieved better experimental results in perceptual quality. The quality of images are obtained by using peak signal noise ratio(PSNR).The PSNR achieved for gray images is 74.79%, for color images is 73.41%,and for text images 83.3%.

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