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Detailed Performance Evaluation of Bilateral Filters for De-noising Chromosome Image

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ABSTRACT
This paper proposes an improved bilateral filter, adaptive Bilateral Filter, Switched Bilateral Filter to remove Gaussian noise from gray images. All the techniques are implemented using simulation in MATLAB- it is found that the standard BF is the best technique to remove Gaussian noise from images with high PSNR value. This technique is implemented in MATLAB-13 and various performance metrics taken into consideration are: Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE), and Normalized Color Difference (NCD) a good picture quality of de-noising images. The result shows that the proposed technique gives the best results than all other techniques in terms of all comparison parameters.
Keywords: - Gaussian noise, bilateral filter, PSNR, MSE, NCD, image de-noising, Chromosome Image.

I. INTRODUCTION
Noise [1] affects the pixel values in the image, which can cause random variation of brightness or color information. It may occur during image capturing, acquisition process, transmission through channel etc. The Gaussian noises are available in literature that affects the image in a different manner as explained below:

Gaussian Noise:
- It mainly occurs in images during acquisition process. It is additive in nature and randomly adds any the number of pixel values .[2]
- Gaussian noise is an idealized form of white noise. White noise is a random signal with flat power spectral density. Gaussian noise is caused due to random fluctuations in the signal. It is also called additive noise as it can be modeled by random values added to an image. B.Sridhar et.al [3] presented the performance analysis of adaptive bilateral filter is evaluated by pixel to noise ratio and mean square errors. The performed values are calculated by changing the parameters of the adaptive filter half width values and standard deviations. The bilateral filtering gives a promising result in the area of image de nosing. . Some of the scholars given a complete theoretical analysis of the bilateral filter and connected with the general approaches [4]. Filtering is one of the most fundamental operations used in image processing. Image smoothing is a technique based on filtering which is utilized by noise reduction methods. In the recent past BF, ABF, SBF and its variants have been proposed in literature to remove single and Gaussian noise. This paper is an effort to compare BF and its variants, and to analyze the efficiency of a specific filter to de-noise from the images.
- This paper deals with the removal of Gaussian noise, the most common form of noise which degrades the image quality. To remove Gaussian noise various filtering techniques are proposed in literature. In this paper we implemented Bilateral Filter, Switching Bilateral Filter (SBF) for the comparison with the proposed Adaptive Bilateral Filter (ABF). The rest of the paper is organized as follows.
- In the Figure 1 the effect of different Gaussian noises on perceptible image quality is shown. It can be easily observed from Figure, that all kind of noises degrade image quality. Therefore, to remove these noises various de-noising mechanism have been proposed in literature. The rest of the paper is organized as follows:

BF

ADF

SBF

Figure.1. Effect of different Gaussian noise Image

In this paper Section 2 provides the literature bilateral filter techniques. Section 3 presents the proposed technique and the simulation setup parameters used in implementation of filtering techniques. Section 4 presents the performance metrics result taken into consideration for comparison. Section 5 conclusions and section 6 references.

II. BILATERAL FILTER TECHNIQUES

This section gives a brief introduction about the various techniques used for de-noising images.

A. Bilateral Filter

Bilateral Filter [3] was first proposed by C. Tomasi, R. Manduchi in the year 1998. It is basically a non-linear, edge-preserving and Gaussian noise reducing filter used for gray and color images. It tries to smoothen the image and at the same time preserves edges of the image. As we know that color images have three bands *i.e.* red, green and blue. If these three bands are filtered separately, the smoothness of the image at the edges will be different. Separate smoothing disturbs the balance of colors and unexpected color combinations may appear. Therefore, bilateral filters operate on three bands of color at once and can tell which colors are similar so that they can be averaged together.

The basic idea of bilateral filtering [5] is that it makes a nonlinear combination of similar pixel values. It filters the image using range and domain filter. For domain filtering, values chosen show the desired amount of combination of pixels, while the range filtering chooses values based on the desired amount of low pass filtering. A low pass domain filter on image I(x) can be defined as

$$(x)=kd-1\ (x)\iint I(y)*c(x,y)dy\infty-\infty$$

Where c(x,y) measures the geometric closeness between the neighborhood center x and a nearby point y, h(x) is the output image and kd(x) is the normalized constant which is calculated as

$$kd(x)=\iint c(x,y)dy\infty-\infty$$

Similarly range filter is defined as

$$(x)=kr-1\iint I(y)*s(I(x),I(y))dy\infty-\infty$$

Now s(f(x),f(y)) measures the photometric similarity between the pixel at the neighborhood center x and that of a nearby point y. The normalized constant (kr) is replaced by

$$kr(x)=\iint s(I(x),I(y))dy\infty-\infty$$

Both geometric and photometric similarity is combined to obtain bilateral filter as follows:

$$h(x)=kr-1\iint I(y)*s(I(x),I(y))\infty-\infty * c(x,y)dy$$

$$kr(x)=\iint s(I(x),I(y))*c(x,y)dy\infty-\infty$$

The normalization term kr(x) shows that the weights for all the pixels. The output image can be redefined as: $s(I(x),I(y))=e-\|I(y)-I(x)\|22\sigma r2\ c(x,y)=e-\|y-x\|22\sigma d2$

Thus, mathematically at a pixel location (x,y) the output I(x,y) of the bilateral filter is calculated as follows

$$I'(x,y)=\Sigma y\in N(x)e-\|y-x\|22\sigma d2e-\|I(y)-I(x)\|22\sigma r2I(x,y)$$

Where σd and σr are parameters controlling the fall-off of weights in spatial and intensity domains, respectively. N(x) is a spatial neighborhood of pixel I(x). σd is the geometric spread parameter that is to be chosen based on the amount of the low pass filtering required. A large value of σd means it combines values from more distance in an image. Similarly σr is the parametric spread that is set to achieve the desired amount of combination of pixel values. Now let us discuss the pros and cons of bilateral filter which will help us in understanding its variants.

Advantages of Bilateral Filter:

• It preserves edges while removing noise and causes smoothening of images.

• While working with color images, it reduces color blurriness.

• It is simple, local and non-iterative scheme to implement.

Disadvantages of Bilateral Filter:

• It cannot be used for removing of impulse noise or mixed noise.

• It replaces each pixel with filtered value whether it is noisy or not.

• It only smoothens image, doesn't sharpens.

B. Adaptive Bilateral Filter

As discussed above, bilateral filter is a smoothening filter and it doesn't sharpen the edges of image. To overcome this limitation, an Adaptive Bilateral filter (ABF) [6] is proposed by Zhang and Allebach in the year 2008 which not only smoothes the image but also sharpens the image by increasing the slope of the edges. ABF adds an offset (φ) to the existing bilateral filter in order to sharpen the edges. The resultant normalization factor ($rm0n0$) is calculated as:

$$rm0n0=\Sigma\exp\ (-(m-m0)2+(n-n0)22\sigma d2m0+\ Nm=m0-N)\times\exp\ (-(g[m,n]-g[m0n0)-\varphi[m0n0])22\sigma r2[m0n0]$$

ABF differs from its previous version in two ways. Firstly an offset φ is introduced to the range filter so as to shift the range filter on the histogram and this causes sharpening of edges. The other modification done is making the width of the range filter, σr adaptive. It helps in identifying which pixel values are similar and needs to be averaged. Now let us discuss merit and demerits of this filter.

Advantages of ABF:

- It sharpens images by increasing the slope of the edges over the conventional bilateral filter.
- By combining offset and range of width filter, the technique becomes much more powerful and versatile. As a result overall quality of de-noised is improved.

Disadvantages of ABF:

- During the process of sharpening of images, ABF tends to posterize the image by pulling up or pushing down pixels along the edge slope.
- ABF does not perform well at corners of an image and does not work for impulse noise and mixed noise

C. Switching Bilateral Filter

All the techniques discussed so far remove only single noise but none of them remove mixed noises *i.e.* image contaminated with two different kinds of noises. To overcome this drawback, a new filtering scheme named as Switching Bilateral filter (SBF) [7] was introduced. It is based upon the "detect and replace" methodology and for detection purpose, we used a noise detector [8] in the switching filtering technique. The absolute difference between current pixel and reference median is calculated. Depending upon the value of absolute difference, we can determine whether the pixel is noisy or not. If the value of absolute difference is large, then the processing pixel is said to have noise otherwise it is noise free. It is very important to choose a proper value of reference median in the given window; otherwise it may lead to false detection of the noisy pixel

Advantages of SBF:

- It removes both types of noise i.e. Gaussian noise and impulse noise while preserving edges without adding any weighting function.
- It includes a noise detector to correctly classify the noisy pixels.
- For any level of noise density window size can be fixed.
- It is non-iterative and only few parameters needed to adjust for best results.

Disadvantages of SBF:

- SBF removes mixed effectively but it has the disadvantage of color blurriness.

III. SIMULATION SETUP

To compare the performance of various Bilateral Filter techniques, a simulator is designed in MATLAB - 13. It evaluates the performance of all the techniques using following performance metrics:

A. Performance Evaluation Metrics

Following parameters are used to measure the performance of various noise removal techniques.

1) ***Mean Square Error:*** It is the cumulative squared error between the final de-noised image and the original image. This enables us to compare mathematically as to which method provides better results. For color image it can be expressed as:
   a. MSE=$1/M\times N\times 3\Sigma c=^{3}1\Sigma y=^{N1\Sigma x}=^{M}1^{Abs}$ $[F^{c}$ $(x, y)-Fc^{\sim}(x, y)]$ ^2

   Where:

   M x N is the size of image (height and width respectively

   C=1 to 3 denotes the Red, Green and Blue color plane respectively

   $F^{c}(x, y)$ =value of pixel at position (x, y) in c color plane of original image

   $F^{c\sim}(x, y)$ =value of pixel at position (x, y) in c color plane of de-noised image

2) ***Peak Signal to Noise Ratio (PSNR):*** It is the measure of quality of the image by comparing de-noised image with original image. It is an expression used to depict the ratio of maximum possible power of image (signal) and the power of the corrupting noise that affects the quality of its representation. It is represented in terms of mean square error as:
   a. PSNR=10log10 (MAX^{2}/MSE)

   MAX is the maximum possible pixel value of the image. It is equal to 255 for 8 bit represented image.

3) **Normalized Color Difference (NCD):** It is used to measure the degradation in color quality in color images since it approaches the human perception. It is defined as:
   a. $NCD_{lab}=\sum^{N}i_{=1\sum}{}^{iM\Delta Elab/}\sum_{Ni=1\sum}{}^{M}{}_{Elab}$

   Where *M*, *N* are the image dimensions.

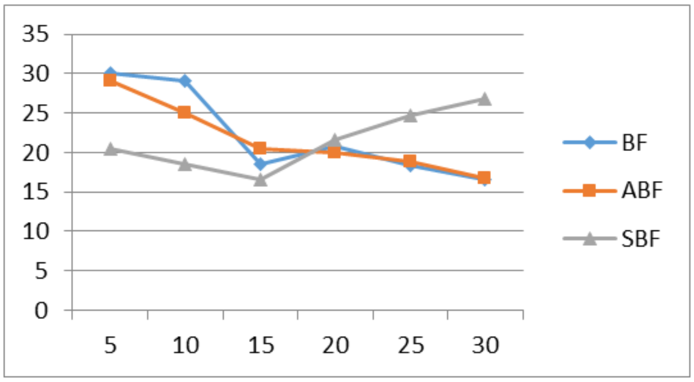
4) ***Perceptual Quality****:* Picture quality is a characteristic of an image that measures the perceived image degradation (typically, compared to an ideal or perfect image). Instead of de-noised image should possess high PSNR and Low MSE, NCD the de-noised image should be smooth, clean and clear also. De-noised image should be so fine for human observer as if it seems Chromosome image.

IV. RESULTS

In this section the simulation results of filtering techniques as discussed above, are compared. Figures 2-4 show the results of PSNR, MSE and NCD respectively

A. Results of PSNR

PSNR for Input Image Chromosome



Standard Deviation of Gaussian Noise

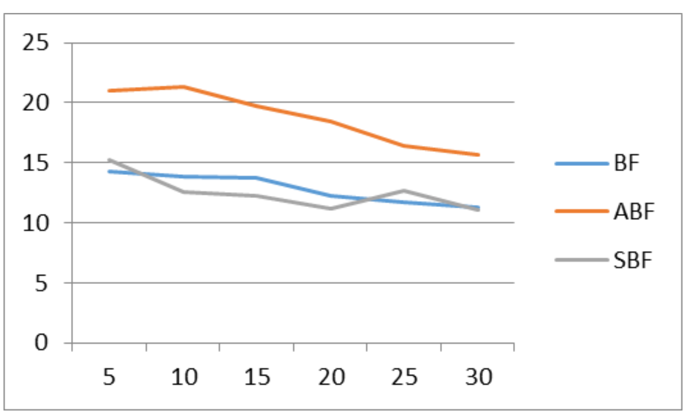
Figure .2. Comparison of PSNR Results for Input Image Chromosome

In Figure 3 the results of PSNR for all variants of BF and proposed technique are shown for standard deviation from 5 to 30. From the results following inferences can be made:

- The proposed filtering technique gives the highest PSNR value when the image is corrupted with Gaussian noise.
- The BF gives the lowest value of PSNR for large values of standard deviation whereas SBF gives lowest PSNR for small values of standard deviation of Gaussian noise.

B. Results of MSE

MSE for input image Chromosome



Standard Deviation of Gaussian Noise

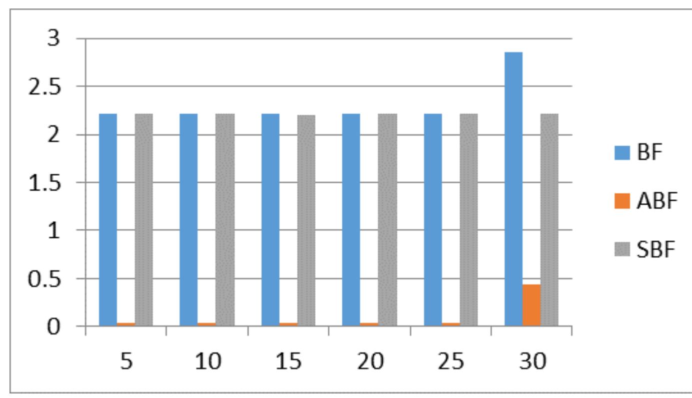
Figure .3. Comparison of MSE Results for Input Image Chromosome

In Figure 4 the results of MSE for all variants of BF and proposed technique are shown for standard deviation from 5 to 30. From the results following inferences can be made:

- The proposed filtering technique gives the lowest MSE value when the image is corrupted with Gaussian noise.
- The ABF gives the highest value of MSE for large values of standard deviation whereas SBF gives large MSE for small values of standard deviation of Gaussian noise.

C. Results of NCD

NCD for input image Chromosome



Standard Deviation of Gaussian Noise

Figure .4. Comparison of NCD Results for Input Image Chromosome

In Figure 6 the results of NCD for all variants of BF and proposed technique are shown for standard deviation from 5 to 30. From the results following inferences can be made:

- The proposed filtering technique gives the lowest NCD value when the image is corrupted with Gaussian noise.
- The BF gives the highest value of NCD for large values of standard deviation whereas ABF gives large NCD for small values of standard deviation.

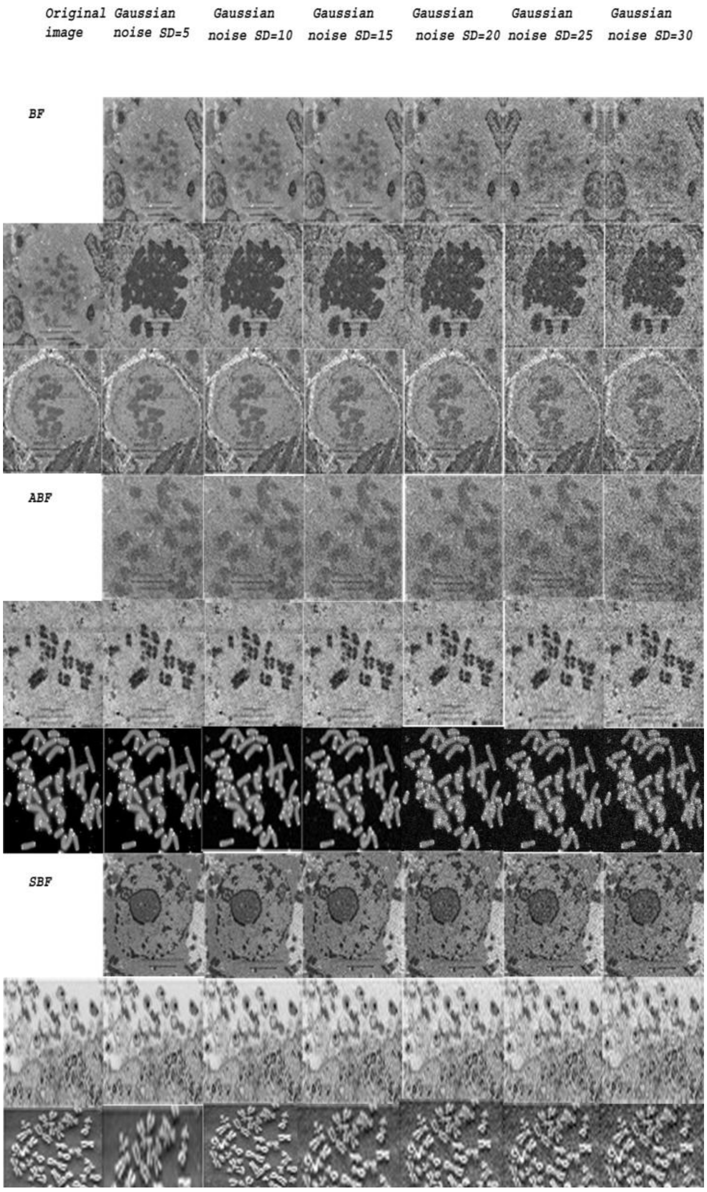
Also the overall results of all filtering techniques are given in Table 2 and Table 3 for σ=5 to 30 for Chromosome images respectively.

Table .1. PSNR, MSE, and NCD for Gaussian Noise Removing Techniques

Standard Deviation	Parameter	BF	ABF	SBF	Proposed
5	PSNR	33.3898	25.0987	20.3456	35.35
	MSE	18.7923	22.2890	20.9870	18.9705
	NCD	2.9206	0.5672	1.9876	0.0191
10	PSNR	28.8174	24.8970	18.9876	30.6419
	MSE	18.0518	21.9087	20.5678	17.7890
	NCD	2.3252	0.0566	1.9867	0.0190
15	PSNR	27.6549	23.8907	16.4567	27.8502
	MSE	17.9876	20.5678	19.9870	17.9087
	NCD	2.9876	0.0565	1.9860	0.0189
20	PSNR	26.9870	22.6780	16.3876	26.2477
	MSE	17.0987	20.4543	18.6780	16.8907
	NCD	2.9876	0.0554	1.7859	0.0176
25	PSNR	26.0987	21.7890	15.6789	24.8669
	MSE	16.9876	20.4562	16.9870	16.3521
	NCD	2.9087	0.0555	1.6854	0.01678
30	PSNR	24.8760	18.8907	14.7890	24.3301
	MSE	14.5677	19.8760	16.0987	15.9875
	NCD	2.9870	0.0552	1.5667	0.0162

The results of perceptual quality are given in Table 4 and 5. From the results it is seen that the proposed technique gives best perceptual quality results.

Table .2. Comparison of Perceptual Quality of De-noised Image Chromosome



IV. CONCLUSION

In this paper various bilateral filter and its variants are reviewed and analyzed based on various performance metrics. The following points can be inferred (see Table 1, 2) from the simulation and results.

The following important inferences can be drawn from the above results as follows:

- The proposed technique gives best results in terms of PSNR, MSE, and NCD values than all other filtering techniques implemented to remove Gaussian noise.
- Proposed technique provides best perceptual quality by edge sharpening and reducing.
- The chromosome image and preserves the edges in a way that is tuned to human performance.
- Design parameters are compared with quality metrics. The main limitation is, this method is not much effective on the image having the corner edges.
- Future development of this method is to be with proposed method the proposed filtering technique works very well for dense noise case of other filtering techniques.

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