



## COMPARATIVE STUDY OF ALGORITHMS/TECHNIQUES FOR DENOISING OF GAUSSIAN NOISE

Vipul Singh

Bachelor of Technology(Hons.) in Information Technology, J.S.S Noida  
City: Bangalore,India

**Abstract :** Noise is a random variation of image intensity and visible as grains in the image. Gaussian noise is one of the noise that can be found in gray as well as colored images. Gaussian noise is a noise that has a random and normal distribution of instantaneous amplitudes over time. Gaussian noise is statistical noise having a probability density function equal to that of the normal distribution, which is also known as the Gaussian distribution. A lot of algorithms and techniques have been developed to remove the Gaussian noise from the image (both gray scale and colored). In this paper, we compare the Bilateral Filter, Block-matching and 3D filtering, Gaussian smoothing Filter, Median Filter and Spatial gradient Bilateral Filter for gray scale images and, Adaptive Bilateral Filter and Sparse 3-D transform-domain collaborative Filter for colored images. A comparative study based on Peak Signal to Noise Ratio and Mean Absolute Error of these algorithms has been provided in this paper.

**Keywords:** image denoising; Gaussian noise; filtering techniques; bilateral filter; block matching; 3D transform; Gaussian smoothing; median filtering;

### 1. INTRODUCTION

Image denoising is a classical yet fundamental problem for image quality enhancement in computer vision and photography systems. Gaussian noise is a statistical noise whose probability density function (PDF) is equal to that of the normal distribution also called Gaussian distribution [1].

Gaussian noise is removed from the digital images by smoothing of the image pixels which helps in reducing the intensity of the noise present in the image which is caused due to acquisition but the result may be sometime undesirable and also which can result in blurring edges of

observation  $y = x + n$ , where  $n$  is generally assumed to be additive white Gaussian noise (AWGN). For colored image, there are mainly three strategies for color image denoising.

- 1) The first strategy is to apply the grayscale image denoising algorithm to each channel.
- 2) The second strategy is to transform the RGB image into a less correlated color space, such as YCbCr, and perform denoising in each channel of the transformed space.
- 3) The third strategy is to perform joint denoising on the RGB channels simultaneously for better use of the spectral correlation.

### 2. SOURCES OF GAUSSIAN NOISE

Principal sources of Gaussian noise in digital images arise during acquisition e.g. sensor noise caused by poor illumination and/or high temperature, and/or transmission. The noise can also come from natural sources, such as the thermal vibration of the atom of the conductors from earth or other warm objects.

### 3. TECHNIQUES/ALGORITHMS TO REMOVE GAUSSIAN NOISE FROM GRAY SCALE IMAGE

Gaussian noise in gray scale images can be removed by the following techniques.

#### A. Bilateral Filter

Bilateral filtering smooths images while preserving edges, by means of a nonlinear combination of nearby image values. It combines gray levels based on both their geometric closeness and their photometric similarity, and prefers near values to distant values in both domain and range. Although some improved methods have been proposed, not all of them have been proved efficient [2, 3].

#### B. Block-matching and 3D filtering (BM3D)

BM3D filter is based on combining sliding-window transform processing with block-matching in 3D transform domain. It undertakes the block-matching concept for a

$$P(x) = \frac{1}{(\sigma\sqrt{2\pi})} * e^{-\frac{(x-\mu)^2}{2\sigma^2}} \quad -\infty < x < \infty$$

the high-quality images pixel value at each point. The PDF of Gaussian random variable is given by:

Gaussian Where:  $P(x)$  is the Gaussian distribution noise in image;  $\mu$  and  $\sigma$  is the mean and standard deviation respectively.

Additive white Gaussian noise (AWGN) is a basic noise model used in Information theory to mimic the effect of many random processes that occur in nature. The modifiers denote specific characteristics:

- Additive because it is added to any noise that might be intrinsic to the information system.
- White refers to the idea that it has uniform power across the frequency band for the information system. It is an analogy to the color white which has uniform emissions at all frequencies in the visible spectrum.
- Gaussian because it has a normal distribution in the time domain with an average time domain value of zero.

Denoising algorithms designed for grayscale images, aiming to recover the clean image  $x$  from its noisy

single noisy image and process in a sliding manner to search for blocks that exhibit similarity to the currently-processed one. The matched blocks are stacked together to form a 3D array. Applying a 3D decorrelating unitary transform which produces a sparse representation of the true signal in 3D transform domain. The results are reconstructed by an inverse 3D transform of the filtered coefficients. After processing all blocks, the final estimate is the weighted average of all overlapping local block-estimates. Marc Dabov, gave the extension of BM3D by combining Wiener Filter[4].

#### C. Gaussian smoothing Filter

Gaussian smoothing uses 2-D distribution as a point-spread function, and this is achieved by convolution. Since the image is stored as a collection of discrete pixels, a discrete approximation to the Gaussian function is done before performing convolution.

#### D. Median Filter

The Median Filter is performed by taking the magnitude of all of the vectors within a mask and sorting the magnitudes [5].

#### E. Spatial gradient Bilateral Filter (SG-BF)

Spatial gradient statistic is introduced into the bilateral filtering framework through replacing the radiometric weighting function. This bilateral filter, named SG-BF, is capable of removing Gaussian noise while keeping edge details. Moreover, spatial gradient can be combined with the directional absolute relative differences (DARD) statistic to create a new trilateral filter, which can remove both Gaussian and impulse noise, Spatial gradient-directional absolute relative differences-trilateral filter SG-DARD-TRIF[6].

### 4. TECHNIQUES/ALGORITHMS TO REMOVE GAUSSIAN NOISE FROM COLORED IMAGE

Gaussian noise in colored images can be removed by the following techniques.

#### A. Adaptive Bilateral Filter

The Adaptive Bilateral filter (ABF) retains the general form of a bilateral filter, but contains two important modifications. First, an offset is introduced to the range filter in the ABF. Second, both the width of the range filter in the ABF are locally adaptive[7, 8, 9, 10].

#### B. Sparse 3-D transform-domain collaborative Filter

Sparse 3-D transform-domain collaborative Filter groups similar 2-D image fragments (blocks) into 3-D data arrays which are called groups. Collaborative filtering is a special procedure developed to deal with these 3-D groups. It involves three successive steps: 3-D transformation of a group, shrinkage of the transform spectrum, and inverse 3-D transformation. The result is a 3-D estimate that consists of the jointly filtered grouped image blocks. By attenuating the noise, the collaborative filtering reveals even the finest details shared by grouped blocks and, at the same time, it preserves the essential unique features of each individual block. The filtered blocks are then returned to their original positions by aggregating the positions. A significant improvement is obtained by a specially developed collaborative Wiener filtering[11].

### 5. COMPARISON

The performance of the aforementioned filters/algorithms have been evaluated and compared for denoising of images for Gaussian noise. The following parameters are being used for comparison.

□ **Peak Signal to Noise Ratio (PSNR):** It is the measure of quality of the image by comparing denoised 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.

The dependency of the PSNR on gaussian noise was deeply studied in the paper[12].

□ **Mean Absolute Error (MAE):** It is the absolute error between the original image and the denoised image. It represents the average value of introduced deviation per pixel with respect to original image.

The gray scale and colored images are compared separately for denoising Gaussian noise.

#### A. Gray scale Images

The techniques/algorithms are tested using 512X512, 8-bits/pixel standard images such as Lena (Gray). Standard deviation taken into consideration are 15 and 20 that will be applied to the various filters. In addition to the visual quality, the performance of the techniques/algorithms are quantitatively measured by the following parameters such as peak signal-to-noise ratio (PSNR) and the mean absolute error (MAE). Also, the pros and cons of each techniques/algorithms are also provided alongside the results in table 1.

#### B. Colored Images

The techniques/algorithms are tested using 256\*256\*3, standard images such as Lena (Colored). Standard deviation taken into consideration are 15 and 20 that will be applied to the various filters. The performance of the techniques/algorithms are quantitatively measured by the following parameters such as peak signal-to-noise ratio (PSNR) and the mean absolute error (MAE) and are tabulated in table 2.

### 6. CONCLUSION

On comparing the results the results of gray scale images and colored images the following conclusion is drawn.

#### A. Gray scale Images

The denoising of gray scale images is more prominent in BM3D and SG-BF compared to others. Since the complexity of SG-BF is more than that of BM3D, the application of SG-BF is limited. Marc Lebrun, provided a complete analysis of BM3D on Gaussian noise[13]. Median and Gaussian smoothing filter are simple but the performance of these filters decreases with increase in noise in the image. Bilateral filter is simple as well as the results of the bilateral filter is comparable to that of BM3D and SG-BF.

#### B. Colored Images

The denoising of colored images is more prominent in Adaptive Filter than in CBM3D. Although adaptive filter is simple and renders a sharp image, CBM3D will take advantage the correlation between red, green and blue

components of the colored image. A more detailed analysis has been provided by Dabov, Kostadin in thesis[15].

Table 1. Comparative denoising for Gaussian noise results in PSNR (dB) and MAE (the second row) for gray scale images.

<i>Sr. No</i>	<i>Algorithm/ Techniques</i>	<i>PSNR</i>	<i>MAE</i>	<i>Pros</i>	<i>Cons</i>
1	Bilateral Filter	30.67	2.785	<ol style="list-style-type: none"> <li>1. Easy to understand, adapt and set up.</li> <li>2. The method is non-iterative and local, thus simple.</li> </ol>	<ol style="list-style-type: none"> <li>1. Hard to analyze because of the nonlinear nature.</li> <li>2. Brute-force implementation is too slow.</li> <li>3. The performance is degraded with high noise level.</li> </ol>
2	BM3D	33.97	2.678	<ol style="list-style-type: none"> <li>1. Preserve textures.</li> <li>2. Retain good visual quality even for relatively high levels of noise.</li> <li>3. The approach uses the non-locality and the collaborative filtering giving advantage over other filters.</li> <li>4. Wiener filtering improves the accuracy and effectiveness of the Wiener filter.</li> </ol>	<ol style="list-style-type: none"> <li>1. Performance decreases if the noise level is high.</li> <li>2. Not effective when a large amount of matching blocks is not found.</li> <li>3. The values of all the parameters are given a priority, irrespective of the type of image and the level of noise provided as input leading to poor denoising performance.</li> </ol>
3	Gaussian smoothing Filter	30.12	2.856	<ol style="list-style-type: none"> <li>1. Simple compared to other techniques.</li> </ol>	<ol style="list-style-type: none"> <li>1. Blurs edges and details.</li> </ol>
4	Median Filter	28.94	3.083	<ol style="list-style-type: none"> <li>1. It preserves the sharp edges.</li> <li>2. A major advantage of the median filter over linear filters is that the median filter can eliminate the effect of input noise values with extremely large magnitudes.</li> </ol>	<ol style="list-style-type: none"> <li>1. Neither Gaussian nor median filters preserve edges, meaning after applying the filter the location of edges in your image will move.</li> <li>2. Difficult to design in comparison to linear filter.</li> </ol>

<i>Sr. No</i>	<i>Algorithm/ Techniques</i>	<i>PSNR</i>	<i>MAE</i>	<i>Pros</i>	<i>Cons</i>
6	SG-BF	30.68	2.764	<ol style="list-style-type: none"> <li>1. Better when standard deviation is large.</li> <li>2. Produces near same results as the bilateral filter.</li> <li>3. Better when image is highly corrupted with Gaussian noise.</li> </ol>	<ol style="list-style-type: none"> <li>1. Complex to implement.</li> <li>2. Slow.</li> </ol>

Table 2. Comparative denoising for Gaussian noise results in PSNR (dB) and MAE (the second row) for colored images.

<i>Sr. No</i>	<i>Algorithm/ Techniques</i>	<i>PSNR</i>	<i>MSE</i>	<i>Pros</i>	<i>Cons</i>
1	Adaptive Bilateral Filter	33.90	1.975	<ol style="list-style-type: none"> <li>1. Provide best perceptual quality by edge sharpening and reducing the color blurriness.</li> <li>2. Works very well for dense noise and does not introduces blurriness as in case of other filtering techniques.</li> <li>3. It renders much sharper images than the bilateral filter does.</li> <li>4. The ABF also achieves better noise suppression than the optimal unsharpmask.</li> <li>5. The method is non-iterative and local, thus simple.</li> </ol>	<ol style="list-style-type: none"> <li>1. Tends to posterize the image, due to its fundamental mechanism of sharpening an image by pulling up or pushing down pixels along the edge slope.</li> <li>2. 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.</li> </ol>
2	CBM3D	35.83	2.341	<ol style="list-style-type: none"> <li>1. CBM3D is a luminance-chrominance color-space transformation on the input noisy image in order to take advantage of the high correlation between the red, the green, and the blue components.</li> </ol>	<ol style="list-style-type: none"> <li>1. Heavily depended on the accuracyof any noise estimation technique used to define their filtering parameters.</li> </ol>

**REFERENCES**

1. “Normal distribution” Wikipedia.[online]. Available: [https://en.wikipedia.org/wiki/Normal\\_distribution](https://en.wikipedia.org/wiki/Normal_distribution) [Accessed: March 2017].
2. C. Tomasi and R. Manduchi, “Bilateral Filtering for Gray and Color Images,” in Proceedings of the 1998 IEEE 6th International Conference on Computer Vision, pp. 839–846, January 1998.
3. C.M. Elad, “On the origin of the bilateral Filter and ways to improve it,” *IEEE Transactions on Image Processing*, vol. 11, no. 10, pp. 1141–1151, 2002. corrupted images,” *IEEE Transactions on Image Processing*, vol. 5, no. 6, pp. 1012–1025, 1996.
4. MarcDabov, Kostadin, et al. "Image denoising with block-matching and 3 D filtering." Proceedings of SPIE. Vol. 6064. No. 30. 2006.
5. Kaur, Sukhjinder. "Noise types and various removal techniques." International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE) Volume 4 (2015).
6. Electronics and Communication Engineering (IJARECE) Volume 4 (2015).
7. Chen, Shuhan, Weiren Shi, and Wenjie Zhang. "An efficient universal noise removal algorithm combining spatial gradient and impulse statistic." *Mathematical Problems in Engineering* 2013 (2013).
8. Kaur, Manjeet, Shailender Gupta, and B. Bhusan. "An improved adaptive bilateral filter to remove gaussian noise from color images." *Int J Signal Process Image Process Pattern Recognit* 8.3 (2015): 49-64.
9. Zhang, Buyue, and Jan P. Allebach. "Adaptive bilateral filter for sharpness enhancement and noise removal." *IEEE transactions on Image Processing* 17.5 (2008): 664-678.
10. Shettar, Jyoti, Ekta Maini, and S. Shreelakshmi. "Image Sharpening & De-Noising Using An Adaptive Bilateral Filter." *International Journal of Innovative Research and Development* 2.11 (2013).

11. Mythili, C., and V. Kavitha. "Efficient technique for color image noise reduction." The research bulletin of Jordan, ACM 1.11 (2011): 41-44.
12. Dabov, Kostadin, et al. "Image denoising by sparse 3-D transform-domain collaborative filtering." IEEE Transactions on image processing 16.8 (2007): 2080-2095.
13. Kaur, Parminder, and Jagroop Singh. "A study on the effect of gaussian noise on PSNR value for digital images." International Journal of Computer and Electrical Engineering 3.2 (2011): 319.
14. Lebrun, Marc. "An analysis and implementation of the BM3D image denoising method." Image Processing On Line 2 (2012): 175-213.
15. Dabov, Kostadin. "Image and video restoration with nonlocal transform-domain filtering." Diss. Thesis for the degree of

Doctor of Science in Technology, Tampere University of Technology, Tampere, Finland (2010).



Vipul Singh received the Bachelor of Technology(Hons) degree in Information Technology from J.S.S, Noida (Uttar Pradesh) in 2016. His area of interest includes Speech Signal Processing, Digital Image Processing, Machine Learning and Artificial Intelligence.