Evaluating the Efficiency of Bilateral Filter

Harsimran Kaur[1], Neetu Gupta[2]
[1]Research Scholar (M.Tech), ECE Deptt, GIMET
[2]Asst. prof, ECE Deptt, GIMET
E-Mail- er.harsimrankaur@gmail.com

Abstract- Bilateral filtering is a simple, non-iterative scheme for texture removal and edge-preserving and noise-reducing smoothing filter. The intensity value at each pixel in an image is replaced by a weighted average of intensity values from nearby pixels. This weight is based on a Gaussian distribution. Thus noise is averaged and signal strength is preserved. Performance parameters of bilateral filter have been evaluated. The design and implementation is done in MATLAB using image processing toolbox. The comparison has shown that the bilateral is quite effective for random and Gaussian noise

Keywords- Filtering, noise, gaussian noise, texture, GUI, artifact, compression

INTRODUCTION

A bilateral filter is non-linear, edge-preserving and noise-reducing smoothing filter[1]. The intensity value at each pixel in an image is replaced by a weighted average of intensity values from nearby pixels. This weight can be based on a Gaussian distribution. This preserves sharp edges by systematically looping through each pixel and adjusting weights to the adjacent pixels accordingly[2].The bilateral filter is defined as:

$$I^{\text{filtered}}(x) = \sum_{x_i \in \Omega} I(x_i) f_r(\|I(x_i) - I(x)\|) g_s(\|x_i - x\|)$$

where:

- $I^{\text{filtered}}$is the filtered image;
- I is the original input image to be filtered;
- X are the coordinates of the current pixel to be filtered;
- $\Omega$is the window cantered in x;
- f_r is the range kernel for smoothing differences in intensities. This function can be a Gaussian function;
- g_s is the spatial kernel for smoothing differences in coordinates. This function can be a Gaussian function.

Gaussian low-pass filtering computes a weighted average of pixel values in the neighbourhood, in which the weights decrease with distance from the neighbourhood centre. However, such an averaging consequently blurs the image. How can we prevent averaging across edges, while still averaging within smooth regions? Bilateral filtering is a simple, non-iterative scheme for edge-preserving smoothing. The basic idea underlying bilateral filtering is to do in the range of an image what traditional filters do in its domain[7],[10].

THE GAUSSIAN CASE

A simple and important case of bilateral filtering is shift-invariant Gaussian filtering, in which both the closeness function *c* and the similarity function *s* are Gaussian functions of the Euclidean distance between their arguments [4].More specifically, *c* is symmetric.

$$c(\xi - \mathbf{x}) = e^{-\frac{1}{2}\left(\frac{d(\xi - \mathbf{x})}{\sigma_d}\right)^2}$$

where

$$d(\xi - \mathbf{x}) = \|\xi - \mathbf{x}\|$$

is the Euclidean distance.

METHODOLOGY USED

The following flowchart gives the procedure of the bilateral filtering algorithm with an image f(x,y).

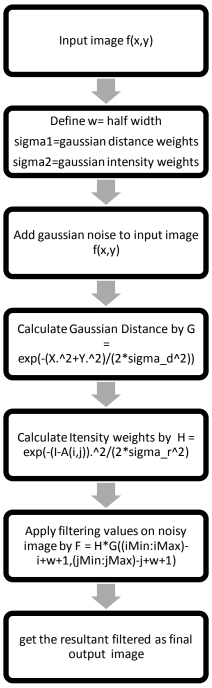

Fig.1 Bilateral filter algorithm

TEST BED

The following table shows the experimental images related to the project with their size and type of format.

TABLE X
IMAGES USED IN SIMULATION

S.No.	TITLE OF THE IMAGE	SIZE	FORMAT
1.	Colg1	2.05 MB	JPG
2.	2	83.3 KB	JPG
3.	Sim1	2.14 MB	JPG
4.	Mandrill	31.6 KB	JPG
5.	fruits	988 KB	JPG

PERFORMANCE PARAMETERS

A good objective quality measure should reflect the distortion on the image well due to, for example, blurring, noise, compression, and sensor inadequacy. Such measures could be instrumental in predicting the performance of vision-based algorithms such as feature extraction, image-based measurements, detection, tracking, and segmentation, etc., tasks. Quantitative measures for image quality can be classified according to two criteria:
1. number of images used in the measurement;
2. nature or type of measurement.
According to the first criterion, the measures are divided into two classes: univariate and bivariate. A univariate measure uses a single image, whereas a bivariate measure is a comparison between two images. A number of measures have been defined to determine the closeness of the degraded and original image fields. On the basis of this a study is done on the following measures and analysed.
1. Pixel difference-based measures: (eg. the Mean Square Error and Maximum Difference).
2. Correlation-based measures: A variant of correlation based measures can be obtained by considering the absolute mean and variance statistics (eg. Structural Correlation / Content, Normalized Cross Correlation) [1],[5].

A. Mean Square Error

In the image coding and computer vision literature, the most frequently used measures are deviations between the original and coded images of which the mean square error (MSE) or signal to noise ratio (SNR) being the most common measures. The reasons for these metrics widespread popularity are their mathematical tractability and the fact that it is often straightforward to design systems that minimize the MSE but cannot capture the artifacts like blur or blocking artifacts. The effectiveness of the coder is optimised by having the minimum MSE at a particular compression and MSE is computed using the following equation:-

$$\text{MSE} = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(f(i,j) - f'(i,j))^2$$

B. Peak Signal – to – Noise-Ratio

Larger SNR and PSNR indicate a smaller difference between the original (without noise) and reconstructed image. The main advantage of this measure is ease of computation but it does not reflect perceptual quality. An important property of PSNR is that a slight spatial shift of an image can cause a large numerical distortion but no visual distortion and conversely a small average distortion can result in a damaging visual artifact, if all the error is concentrated in a small important region[12].This metric neglects global and composite errors PSNR is calculated using the following equation:

$$\text{PSNR} = 20\log_{10}\left(\frac{N}{\text{RMSE}}\right)\ \text{dB}$$

C. Average Difference

A lower value of Average Difference (AD) gives a “cleaner” image as more noise is reduced and it is computed using following equation:

$$\text{Average Difference (AD)} = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}[f(i,j) - f'(i,j)]$$

D. Maximum Difference

Maximum difference (MD) is calculated using the given equation and it has a good correlation with MOS for all tested compression techniques so this is preferred as a very simple measure as a reference for measuring compressed picture quality in different compression systems. Large value of MD means that the image is of poor quality.

$$\text{Maximum Difference (MD)} = Max(|f(i,j) - f'(i,j)|)$$

SIMULATION RESULTS

The bilateral filtering algorithm is applied to the experimental images which are displayed in GUI(Graphic User Interface).It has ‘LOAD’ button to browse the image, ‘APPLY’ button to apply filtering action, ‘CLOSE’ button for closing the GUI window. The following snapshots show the simulation results.

Fig. 2 Applying filtering algorithm

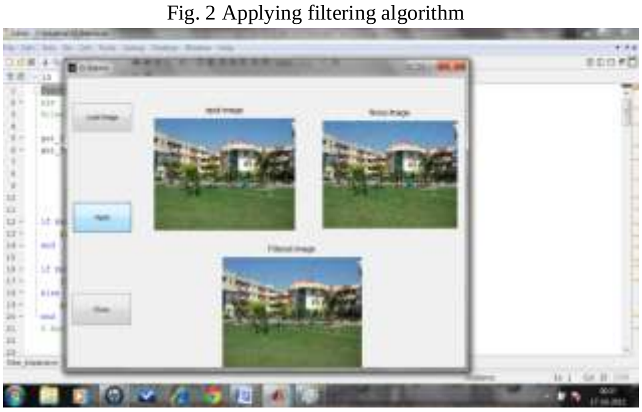

Fig. 3 Filtered image after applying bilateral filtering

Efficiency parameters i.e. values obtained from the bilateral filtering action applied on image no.1 from table 1.1

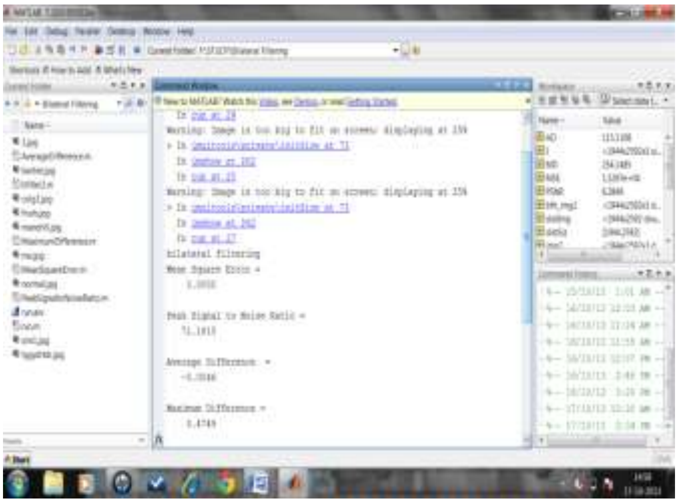

Fig. 4 performance parameters

On comparison with other (median) filter, the values obtained for the same image:

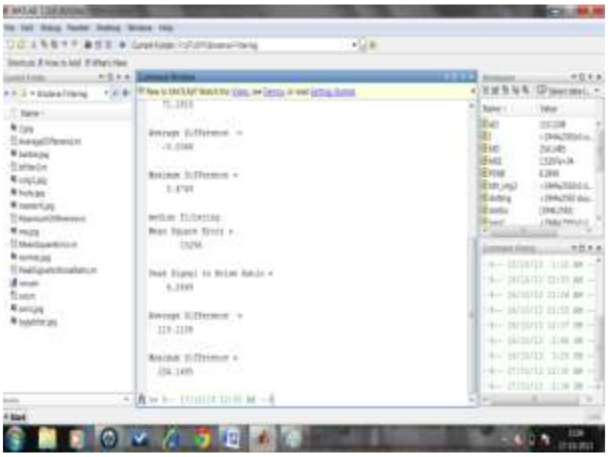

Fig. 5 (contd.) performance parameters

TABLE XII

EFFICIENCY PARAMETERS

S.No.	PARAMETER	BILATERAL FILTER	MEDIAN FILTER
1.	Mean square error	0.0050	15296
2.	Peak SNR	71.1815	6.2849
3.	Average difference	-0.0046	115.1108
4.	Maximum difference	0.4749	254.1485

Evaluation: The values obtained of different parameters are mentioned in the tables above. The study shows that the bilateral filter has greater efficiency .For e.g. if we consider image no. 1, the peak SNR is higher in case of bilateral filter than the median filter[9],[11]. Similarly, other parameter values depict the higher efficiency of the bilateral filter.

VII . CONCLUSION

The work has presented a detailed study on the bilateral filtering technique. By conducting the survey we have found that the bilateral filter is based on the concept of Gaussian distribution. The bilateral filter is a non linear filter and also it reduces the noise in such a way that it preserves the edges. The survey has shown that the bilateral filter is quite effective for random noise so that is why it is more preferable over others. The design and implementation is done in MATLAB using image processing toolbox. The comparison has shown that the bilateral is quite effective for random and Gaussian noise.

FUTURE SCOPE

- To enhance the visibility of digital images.
- To reduce the random noise from the images.
- To remove the fog or haze from the images.
- To filter in such a way that it can preserves the edges.

As it is known bilateral filter is unable to remove salt and pepper noise so in near future we will extend this research work by integrating the bilateral filter with median filter. Because we know that the median filter can remove salt and pepper noise.

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