Comparative Analysis of Image Restoration Algorithms Using Safety Window

Sunita
IRDE, DRDO, Ministry of Defence, Dehradun, India
E-mail: sunnidma@yahoo.com

Chanda Thapliyal
D.A.V. (PG) College
Dehradun, Uttarakhand 248001, India
E-mail: chanda.nautiyal@gmail.com

Abstract

In this paper a comparative performance analysis is carried out among three different clutter removal algorithms such as Max filter, Min filter, and Geometric Mean filter. New algorithms for these three filters with safety window, to reduce the bias, due to the target are proposed in this paper. These new algorithms are compared for blurred image. It leads to the important conclusion about the selection of the filter having the best performance in a given scenario. Experimental result shows that the proposed algorithms with safety window are more efficient than the existing techniques.

Keywords: Max filter, Min filter, Geometric Mean filter, safety window, SNR.

1. Introduction

The problem of image deblurring is to restore high-frequency information from blurred & noisy image. Significant work has been done in both hardware and software to improve the signal to noise ratio in digital photography. See Refs. 2 and 3 for more details. In software, a smoothing filter is used to remove noise from an image. Each pixel is studied and a smoothing filter takes into account the surrounding pixels to derive a more accurate version of this pixel. By taking neighboring pixels into consideration, extreme "noisy" pixels can be replaced. However pixels may represent uncorrupted fine details, which may be lost due to the smoothing process. This paper examines following three smoothing algorithms and introduces these smoothing algorithms with safety window:

- Max- Filter
- Min- Filter
- Geometric-Mean Filter
- Max- Filter with safety window (Max-S)
- Min- Filter with safety window (Min-S)
- Geometric-Mean Filter with safety window (Geomean-S)

2. Problem Descriptions

It is posed mathematically as reconstruction of the initial image *t** from blurry and noisy observation *s** using the model in Ref. 4.

$$s^*(i,j) = t^*(i,j)\ b^*(i,j) + n^*(i,j)$$

Where *t* b** is a convolution of initial image *t** with a blur operator *b**, *n** is a noise. In this paper, averaging filter is taken as a blur operator *b**.

The procedure of noise removal consists of subtraction of the estimate of the background $\hat{b}(i,j)$ obtained by means of filtering from the original image $s^*(i,j)$. The generic pixel after clutter removal is

$$y(i,j) = s^*(i,j) - \hat{b}(i,j)$$

In this paper, $\hat{b}(i,j)$ is calculated by following filters:

2.1. *Max Filter*

The max filter plays a key role in low level image processing and vision. It is identical to the mathematical morphological operation: dilation. The brightest pixel gray level values are identified by this filter. Mathematically, the background estimates $\hat{b}(i, j)$ by the Max- filter can be expressed as

$$\hat{b}_{Max} = \max\{z_1, z_2, z_3, z_4\}$$
$$where$$
$$z_1 = \{s(i, j-N),..., s(i, j),..., s(i, j+N)\}$$
$$z_2 = \{s(i-N, j),..., s(i, j),..., s(i+N, j)\}$$
$$z_3 = \{s(i+N, j-N),..., s(i, j),..., s(i-N, j+N)\}$$
$$z_4 = \{s(i-N, j-N),..., s(i, j),..., s(i+N, j+N)\}$$

It reduces the intensity variation between adjacent pixels. Implementation of this method for smoothing images is easy and also reduces the amount of intensity variation between one pixel and the next. The result of this filter is the max selection processing in the sub image area.

2.2. *Min Filter*

The min filter plays a significant role in image processing and vision. It is equivalent to the mathematical morphological operation: erosion [5] . It recognizes darkest pixels gray value and retains it by performing min operation. The background estimates $\hat{b}(i, j)$ by this filter can be expressed as:

$$\hat{b}_{Min} = \max\{z_1, z_2, z_3, z_4\}$$
$$where$$
$$z_1 = \min\{s(i, j-N),..., s(i, j),..., s(i, j+N)\}$$
$$z_2 = \min\{s(i-N, j),..., s(i, j),..., s(i+N, j)\}$$
$$z_3 = \min\{s(i+N, j-N),..., s(i, j),..., s(i-N, j+N)\}$$
$$z_4 = \min\{s(i-N, j-N),..., s(i, j),..., s(i+N, j+N)\}$$

It removes noise better than max filter. In this filter each output pixel value can be calculated by selecting maximum of minimum gray level values of the chosen area.

2.3. *Geometric Mean Filter*

For the gray level of pixel, the geometric mean filter replaces the gray level by taking into account the surrounding details and attenuating the noise by lowering the variance. This filter is known as smoothing spatial filter, with the median and geometric mean filters outperforming the arithmetic mean filter in reducing noise while preserving edge details. The geometric mean filter is member of set of nonlinear mean filters. The background estimates $\hat{b}(i, j)$ by the geometric mean filter can be expressed as:

$$\hat{b}_{geomean} = \max\{z_1, z_2, z_3, z_4\}$$
$$where$$
$$z_1 = geomean\{s(i, j-N),..., s(i, j),..., s(i, j+N)\}$$
$$z_2 = geomean\{s(i-N, j),..., s(i, j),..., s(i+N, j)\}$$
$$z_3 = geomean\{s(i+N, j-N),..., s(i, j),..., s(i-N, j+N)\}$$
$$z_4 = geomean\{s(i-N, j-N),..., s(i, j),..., s(i+N, j+N)\}$$

3. Proposed Max, Min, and Geomean filter with safety window

Small targets introduce a bias in the directional operations. To cope with this problem we propose the max –filter, min- filter and geometric mean filters with safety window. In the proposed safety window solution, a region around the pixel (i, j) is not included. This region is called safety window centered on the observed pixel (i, j) and having size $(2S+1)\times(2S+1)$ are excluded from the operations of above three filters. S should be less than N (S < N). Safety window is used to collect the local background samples.
We have taken following combinations [Table1] of the window having sizes (2N+1) X (2N+1) and safety window having sizes (2S + 1)X (2S + 1) for the simulation.

Table 1. Combinations of window having size (2N+1) X (2N+1) and guard window having size (2S+1) X (2S+1). (S<N).

(2N+1)X(2N+1)	(2S+1)X(2S+1)
N=2	S=1
N=3	S= 1, 2
N=4	S=1, 2, 3

To compare the algorithms on a quantitative basis, SNR (Signal to Noise Ratio) is calculated for the filtered image using following relation

$$SNR_{out} = 20\log_{10}\left(\frac{s_{\max} - m_B}{\sigma_B}\right)$$

where s_{max} is peak value of the target
m_B is mean variance of the background
σ_B is standard deviation of the background

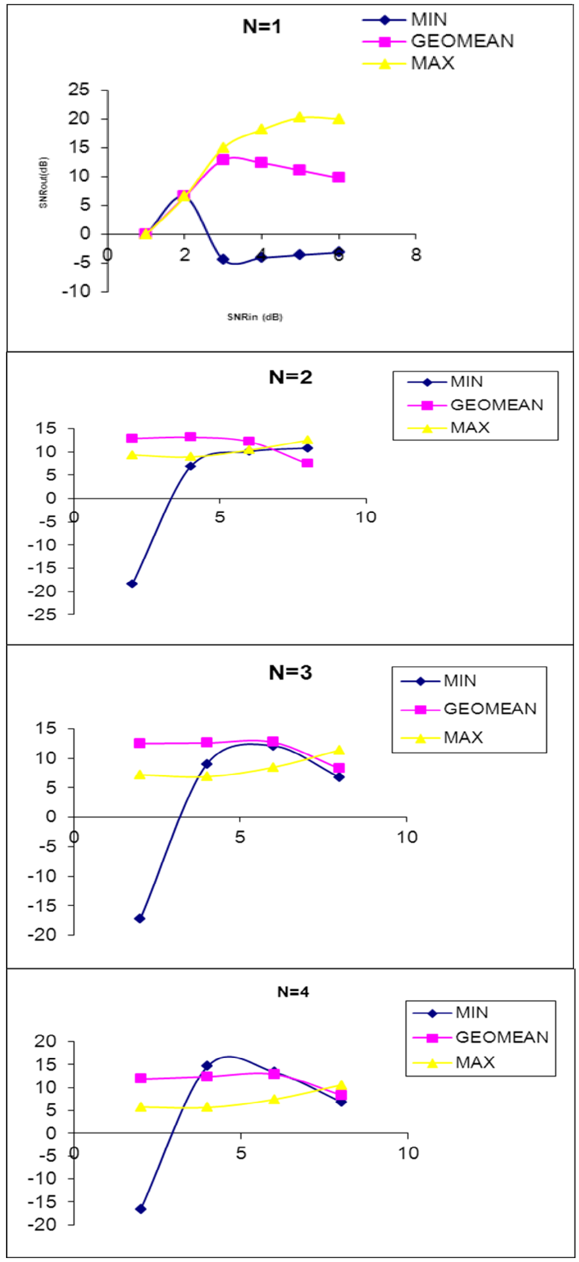
4. Simulation Result

For simulation, medical image of brain (MRI of Brain - Matlab Image) is taken. This is further blurred. The robustness to the target leakage is measured by the SNR at the output of the noise removal system (SNRout) for a fixed value of the SNR in original image (SNRin). So in simulating the targets, the problem arises of the choice of SNRin. Of course the choice of that parameter influences the performance of the algorithms. To evaluate the algorithms, we introduced synthetic target having fixed values of SNRin like 2, 4, 6, 8,10db. We have taken small values for SNR which represent a sort of worst case for background removal methods affected by the target-induced bias in the background estimate. Size of image frame is 100 X 100. The algorithms have been tested for the blurred (Averaging Filter) and noisy image.

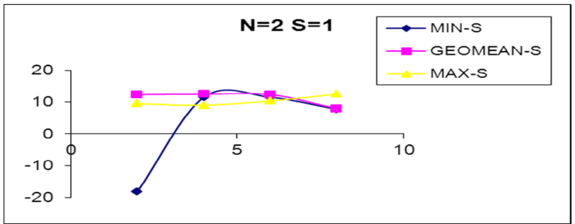
In order to test the performance, each algorithm with respect to the size of the 2-D sliding window, SNRout has been evaluated for different values of N. For SNRout, a unique relationship with N cannot be determined. In fact for each algorithm, SNRout depends on the filter length and on the characteristic of the background region surrounding the target pixel.

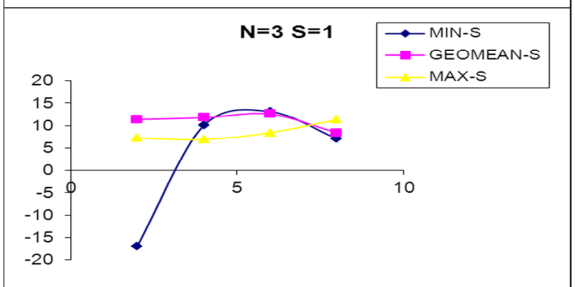
For simulation, the algorithms have been tested for the following four cases using Max- filter, Min- filter, Geometric mean filter, Max-S, Min-S, Geometric mean-S filter.

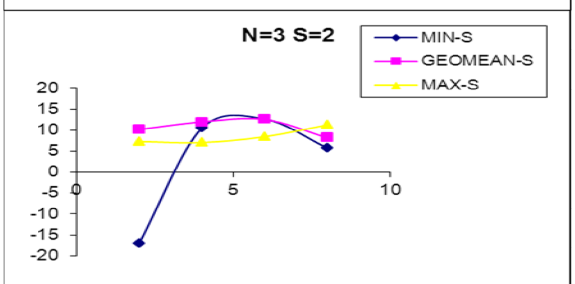
Graphical result by Max- filter, Min- filter, Geomean filter

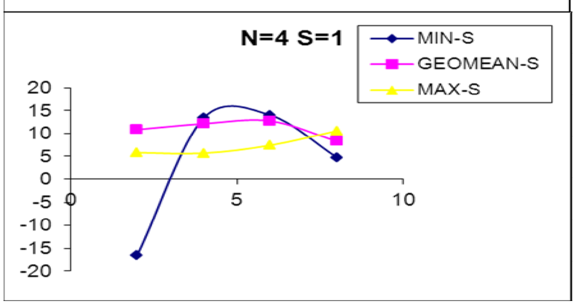


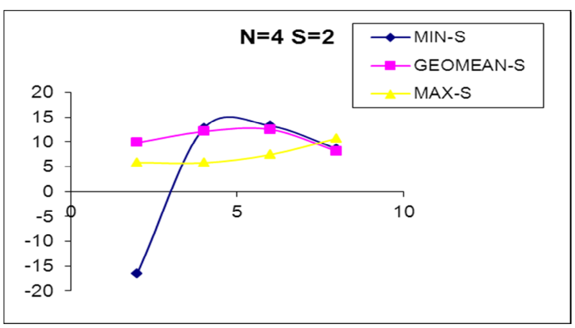
Graphical result by Max- filter, Min- filter, Geomean-filter With Safety Window

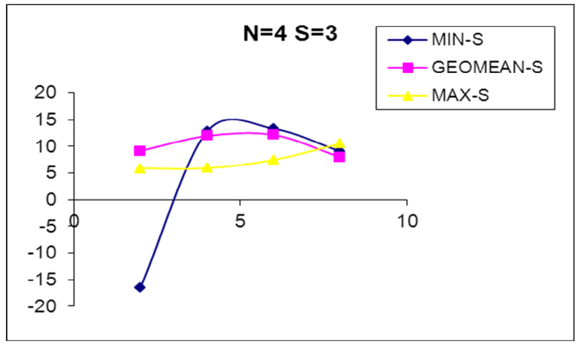












5. Conclusion

In this work, the performance of background removal techniques based on different 2-D filters (max –filter, min-filter and geometric mean filter) has been compared. A modified version of these three algorithms including a safety window has also been defined in order to reduce the bias due to the target. The capabilities of suppressing the background structure and of preserving the target of interest have been quantitatively evaluated by defining SNRout. The results have also confirmed that the Geometric-mean algorithm obtained by introducing a safety window is more efficient in target preservation which is having very low SNR approximately 2dB.

6. References

1. N. Acito, G Corsini, M. Diani, and G. Pennucci *Comparative Analysis of Clutter Removal Techniques Over Experimental IR Images* (Optical Engineering, 2005), 44 (10), 106401.
2. K. Arulmozhi, S. Perumal Arumuga, K. Kannan, and S. Bharathi *Contrast Improvement of Radiographic Images in Spatial Domain by Edge Preserving Filters* (International Journal of Computer Science and Network Security (IJCSNS), 2010), Vol. 10, No. 2.
3. C.Church James, Yixin Chen, and Rice V. Stephen. *A Spatial Median Filter for Noise Removal in Digital Images* (IEEE, 2008)
4. K. Jain Anil. *Fundamentals of Digital Image Processing* (Pearson Prentice Hall, 2006)
5. P. Soille, *Mathematical image analysis: principles and applications* (Springer- Verlag, 1999).