VOL. 6, NO. 2, FEBRUARY 2011 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

NEW HYBRID FILTERING TECHNIQUES FOR REMOVAL OF GAUSSIAN NOISE FROM MEDICAL IMAGES

Gnanambal Ilango[1] and R. Marudhachalam[2]
[1]Postgraduate and Research Department of Mathematics, Government Arts College (Autonomous), Coimbatore, Tamilnadu, India
[2]Department of Mathematics, Kumaraguru College of Technology, Coimbatore, Tamilnadu, India
E-Mail: marudhu14@gmail.com

ABSTRACT

The most significant feature of diagnostic medical images is to reduce Gaussian noise which is commonly found in medical images and make better image quality. In recent years, technological development has significantly improved analyzing medical imaging. This paper proposes different hybrid filtering techniques for the removal of Gaussian noise, by topological approach. The filters are treated in terms of a finite set of certain estimation and neighborhood building operations. A set of such operations is suggested on the base of the analysis of a wide variety of nonlinear filters described in the literature. The quality of the enhanced images is measured by the statistical quantity measures: Root Mean Square Error (RMSE) and Peak Signal-to-Noise Ratio (PSNR).

Keywords: Digital topological neighborhood, brain tumor image, Gaussian noise, RMSE, PSNR.

1. INTRODUCTION

In the early development of image processing, linear filters were the primary tools for image enhancement and restoration. Their mathematical simplicity and the existence of some desirable properties made them easy to design and implement. Moreover, linear filters offered satisfactory performance in many applications. However, they have poor performance in the presence of non additive noise and in situations where system nonlinearities or Gaussian statistics are encountered [5]. In image processing applications, linear filters tend to blur the edges and do not remove Gaussian and mixed Gaussian impulse noise effectively. Previously, a number of schemes have been proposed for Gaussian mitigation. Inherently noise removal from image introduces blurring in many cases. An adaptive standard recursive low pass filter is designed by Klaus Rank and Rolf Unbehauen [6] considered the three local image features edge, spot and flats as adaptive regions with Gaussian noise. Median filter has been introduced by Tukey [12] in 1970. It is a special case of non-linear filters used for smoothing signals. Median filter now is broadly used in reducing noise and smoothing the images. Hakan *et al.*, [3] have used topological median filter to improve conventional median filter. The better performance of the topological median filters over conventional median filters is in maintaining edge sharpness. Yanchun *et al.*, [13] proposed an algorithm for image denoising based on Average filter with maximization and minimization for the smoothness of the region, unidirectional Median filter for edge region and median filter for the indefinite region. It was discovered that when the image is corrupted by both Gaussian and impulse noises, neither Average filter nor Median filter algorithm will obtain a result good enough to filter the noises because of their algorithm. An improved adaptive median filtering method for denoising impulse noise reduction was carried out by Mamta Juneja *et al.*, [7]. An adaptive median filter (AMF) is the best filter to remove salt and pepper noise of image sensing was shown by Salem Saleh Al-amri *et al.*, [10]. The Computer Tomography images were denoised using curvelet and wavelet transforms by Sivakumar [11]. The objective of this study is to develop new hybrid filtering techniques and investigate their performance on medical images.

This work is organized as follows: Section 2 discusses types of noises involved in medical imaging. In Section 3 basic definitions are introduced. Section 4 discusses the various existing filtering techniques for de-noising the medical images. Section 5 deals with proposed hybrid filtering techniques for de-noising the Gaussian noise in the medical images. In Section 6, both quantitative (RMSE and PSNR) and qualitative comparisons are provided. Section 7 puts forward the conclusion drawn by this paper.

2. TYPES OF NOISES

2.1 Salt and pepper noise

Salt and pepper noise is a form of noise typically seen on images. It represents itself as randomly occurring white and black pixels. A “spike” or impulse noise drives the intensity values of random pixels to either their maximum or minimum values. The resulting black and white flecks in the image resemble salt and pepper. This type of noise is also caused by errors in data transmission.

2.2 Speckle noise

Speckle noise affects all inherent characteristics of coherent imaging, including medical ultra sound imaging. It is caused by coherent processing of backscattered signals from multiple distributed targets. Speckle noise is caused by signals from elementary scatterers. In medical literature, speckle noise is referred to as ‘texture’ and may possibly contain useful diagnostic information. For visual interpretation, smoothing the texture may be less desirable. Physicians generally have a preference for the original noisy images, more willingly, than the smoothed versions because the filter, even if they

VOL. 6, NO. 2, FEBRUARY 2011 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

are more sophisticated, can destroy some relevant image details. Thus it is essential to develop noise filters which can preserve the features that are of interest to the physician. Several different methods are used to eliminate speckle noise, based upon different mathematical models of the phenomenon. In our work, we recommend hybrid filtering techniques for removing speckle noise in ultrasound images. The speckle noise model has the following form ($\cdot$ denotes multiplication). For each image pixel with intensity value f_{ij} ($1 \le i \le m$, $1 \le j \le n$ for an m x n image), the corresponding pixel of the noisy image g_{ij} is given by,

$$g_{i,j} = f_{i,j} + f_{i,j} \cdot n_{i,j} \qquad (2.1)$$

where, each noise value n is drawn from uniform distribution with mean 0 and variance σ^2.

2.3 Gaussian noise

Gaussian noise is statistical noise that has a probability density function (abbreviated pdf) of the normal distribution (also known as Gaussian distribution). In other words, the values that the noise can take on are Gaussian-distributed. Gaussian noise is properly defined as the noise with a Gaussian amplitude distribution. Noise is modeled as additive white Gaussian noise (AWGN), where all the image pixels deviate from their original values following the Gaussian curve. That is, for each image pixel with intensity value f_{ij} ($1 \le i \le m$, $1 \le j \le n$ for an m x n image), the corresponding pixel of the noisy image g_{ij} is given by,

$$g_{i,j} = f_{i,j} + n_{i,j} \qquad (2.2)$$

where, each noise value n is drawn from a zero -mean Gaussian distribution.

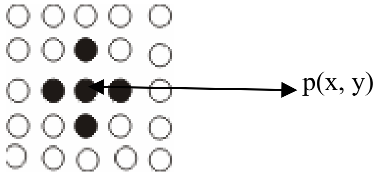
3. BASIC DEFINITIONS

This section presents some general definitions and digital topological results, which will be used along the development of this paper.

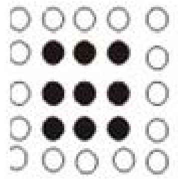
Definition 3.1: [9] A digital image is a function f: ZxZ $\rightarrow$ [0, 1,…….N$-$1] in which N$-$1 is a positive whole number belonging to the natural interval [1, 256]. The functional value of 'f' at any point p(x,y) is called the intensity or gray level of the image at that point and it is denoted by f(p).

Definition 3.2: [9] A neighborhood of a point p ε X is a subset of X which contains an open set containing p. It is denoted by N (p).

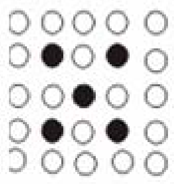
Definition 3.3: [9] The 4-neighbours of a point p(x,y) are its four horizontal and vertical neighbours (x ∓ 1, y) and (x, y $\mp$ 1). The point 'p' and its 4-neighbours is denoted by N_4(p).



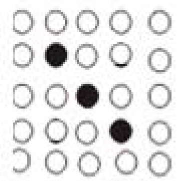
Definition 3.4: [9] The 8-neighbours of a point p(x,y) consist of its 4-neighbours together with its four diagonal neighbours (x + 1,y$\mp$ 1) and (x$-$1,y $\mp$ 1). The point 'p' and its 8-neighbours is denoted by N_8(p).



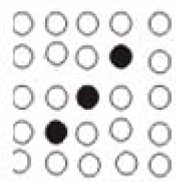
Definition 3.5: The cross neighbours of a point p(x,y) consists of the neighbours (x + 1,y$\mp$ 1) and (x$-$1,y$\mp$ 1). The point 'p' and its cross neighbours is denoted by C_4(p).



Definition 3.6: The LT neighbours of a point p(x,y) consists of the neighbours (x$-1, y-1$) and (x+$1, y+1$). The point 'p' and its LT neighbours is denoted by L_3(p).



Definition 3.7: The RT neighbours of a point p(x,y) consists of the neighbours (x$-1, y+1$) and (x+$1, y-1$). The point 'p' and its RT neighbours is denoted by R_3(p).



4. SOME EXISTING FILTERING TECHNIQUES

In this section, we provide the definitions of some existing filters. The image processing function in a spatial domain can be expressed as

$$g(p) = \Upsilon(f(p)) \qquad (4.1)$$

VOL. 6, NO. 2, FEBRUARY 2011 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

where Υ is the transformation function, f (p) is the pixel value (intensity value or gray level value) of the point p(x, y) of input image, and g(p) is the pixel value of the corresponding point of the processed image.

4.1. Median filter (MF)

The best-known order-statistic filter in digital image processing is the median filter. It is a useful tool for reducing salt-and- pepper noise in an image. The median filter [12] plays a key role in image processing and vision. In median filter, the pixel value of a point p is replaced by the median of pixel value of 8-neighborhood of a point 'p'. The operation of this filter can be expressed as:

$$g(p) = \text{median}\{f(p), \textit{where } p \epsilon N_8(p)\} \quad (4.2)$$

The median filter is popular because of its demonstrated ability to reduce random impulsive noise without blurring edges as much as a comparable linear lowpass filter. However, it often fails to perform well as linear filters in providing sufficient smoothing of nonimpulsive noise components such as additive Gaussian noise. One of the main disadvantages of the basic median filter is that it is location-invariant in nature, and thus also tends to alter the pixels not disturbed by noise.

4.2. Hybrid median filter (HMF)

Hybrid Median filter [4] is of nonlinear class that easily removes impulse noise while preserving edges. The hybrid median filter plays a key role in image processing and vision. In comparison with basic version of the median filter, hybrid one has better corner preserving characteristics. This filter is defined as

$$g(p) = \textit{median}\begin{Bmatrix} \text{median}\{f(p),\ p\epsilon N_4(p)\}, \\ \text{median}\{f(p),\ p\epsilon C_4(p)\}, \\ f(p) \end{Bmatrix} \quad (4.3)$$

A hybrid median filter preserves edges much better than a median filter. In hybrid median filter the pixel value of a point p is replaced by the median of median pixel value of 4-neighborhood of a point 'p', median pixel value of cross neighbours of a point 'p' and pixel value of 'p'.

5. PROPOSED HYBRID FILTERING TECHNIQUES

In this section, we will provide the definition of proposed hybrid filters. These filters are yet to be applied by researchers to remove the Gaussian noise in the ultrasound medical images.

5.1. Hybrid cross median filter (H_1F)

The hybrid cross median filter is a nonlinear filtering technique for image enhancement. It is proposed for Gaussian noise removal from the medical image. It is expressed as:

$$g(p) = \textit{median}\begin{Bmatrix} \text{median}\{f(p),\ p\epsilon L_3(p)\}, \\ \text{median}\{f(p),\ p\epsilon R_3(p)\}, \\ f(p) \end{Bmatrix} \quad (5.1)$$

In hybrid cross median filter, the pixel value of a point p is replaced by the median of median pixel value of LT neighbours of a point 'p', median pixel value of RT neighbours of a point 'p' and pixel value of 'p'.

5.2. Hybrid min filter (H_2F)

Hybrid min filter plays a significant role in image processing and vision. Hybrid min filter is not a usual min filter. Min filter [1] recognizes the darkest pixels gray value and retains it by performing min operation. In min filter each output pixel value can be calculated by selecting minimum gray level value of N_8(p). H_2F filter is used for removing the salt noise from the image. Salt noise has very high values in images. It is also proposed for Gaussian noise removal from the medical image. It is expressed as:

$$g(p) = \textit{min}\begin{Bmatrix} \text{median}\{f(p),\ p\epsilon L_3(p)\}, \\ \text{median}\{f(p),\ p\epsilon R_3(p)\}, \\ f(p) \end{Bmatrix} \quad (5.2)$$

In hybrid min filter, the pixel value of a point p is replaced by the minimum of median pixel value of LT neighbours of a point 'p', median pixel value of RT neighbours of a point 'p' and pixel value of 'p'.

5.3. Hybrid max filter (H_3F)

Hybrid max filter is not a usual max filter. Hybrid max filter plays a key role in image processing and vision. The brightest pixel gray level values are identified by max filter. In max filter [1] each output pixel value can be calculated by selecting maximum gray level value of N_8 (p). H_3F filter is used for removing the pepper noise from the image. It is also proposed for Gaussian noise removal from the medical image. It is expressed as:

$$g(p) = \textit{max}\begin{Bmatrix} \text{median}\{f(p),\ p\epsilon L_3(p)\}, \\ \text{median}\{f(p),\ p\epsilon R_3(p)\}, \\ f(p) \end{Bmatrix} \quad (5.3)$$

In hybrid max filter, the pixel value of a point p is replaced by the maximum of median pixel value of LT neighbours of a point 'p', median pixel value of RT neighbours of a point 'p' and pixel value of 'p'.

6. EXPERIMENTAL RESULTS, ANALYSIS AND DISCUSSIONS

The proposed hybrid filtering techniques have been implemented using MATLAB 7.0. The performance of various hybrid filtering techniques is analyzed and discussed. The measurement of medical image enhancement is difficult and there is no unique algorithm available to measure enhancement of medical image. We use statistical tool to measure the enhancement of medical

VOL. 6, NO. 2, FEBRUARY 2011 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

images. The Root Mean Square Error (RMSE) and Peak Signal-to-Noise Ratio (PSNR) are used to evaluate the enhancement of medical images.

$$\text{RMSE} = \sqrt{\frac{\sum (f(i,j) - g(i,j))^2}{mn}} \quad (6.1)$$

$$\text{PSNR} = 20\log_{10}\frac{255}{RMSE} \quad (6.2)$$

Here f (i,j) is the original brain tumor image with Gaussian noise , g(i,j) is an enhanced image and m and n are the total number of pixels in the horizontal and the vertical dimensions of the image. If the value of RMSE is low and value of PSNR is high then the enhancement approach is better. The original noisy image and filtered image of brain tumor obtained by various hybrid filtering techniques are shown in Figure-1. Table-1 shows the proposed hybrid filtering techniques that are compared with some existing filtering techniques namely, HMF and MF with regard to medical images for brain tumor.

Table-1 shows the RMSE and PSNR values for noisy image of variance 0.2, after 7^{th} iteration.

Table-1

Filters	H_1F	H_2F	H_3F	HMF	MF
RMSE	2.4716	3.8047	0.2205	1.7640	1.0328
PSNR	40.2719	36.5250	61.2639	43.2012	47.8509

Chart-1: Analysis of RMSE and PSNR values of brain tumor images corrupted by Gaussian noise of variance 0.2, after 7^{th} iteration.

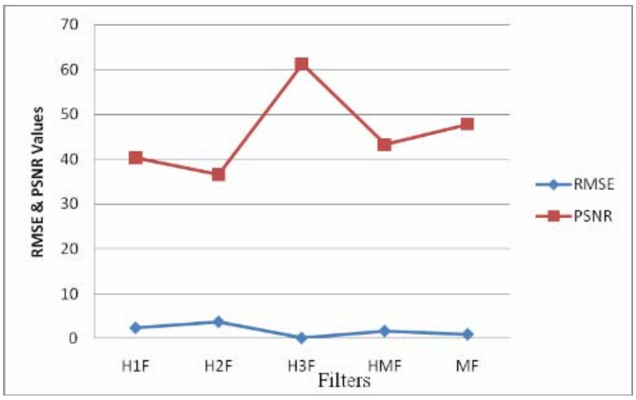


Chart-1

Figure-1 shows denoising of brain tumor image corrupted by Gaussian noise of variance of 0.2, after 7^{th} iteration.

7. CONCLUSIONS

In this work, we have introduced various hybrid filtering techniques for removal of Gaussian noise from medical images. To demonstrate the performance of the proposed techniques, the experiments have been conducted on brain tumor image to compare our methods with many other well known techniques. The performance of Gaussian noise removing hybrid filtering techniques is measured using quantitative performance measures such as RMSE and PSNR. The experimental results indicate that the one of the proposed hybrid filter, Hybrid Max Filter performs significantly better than many other existing techniques and it gives the best results after successive iterations. The proposed method is simple and easy to implement.

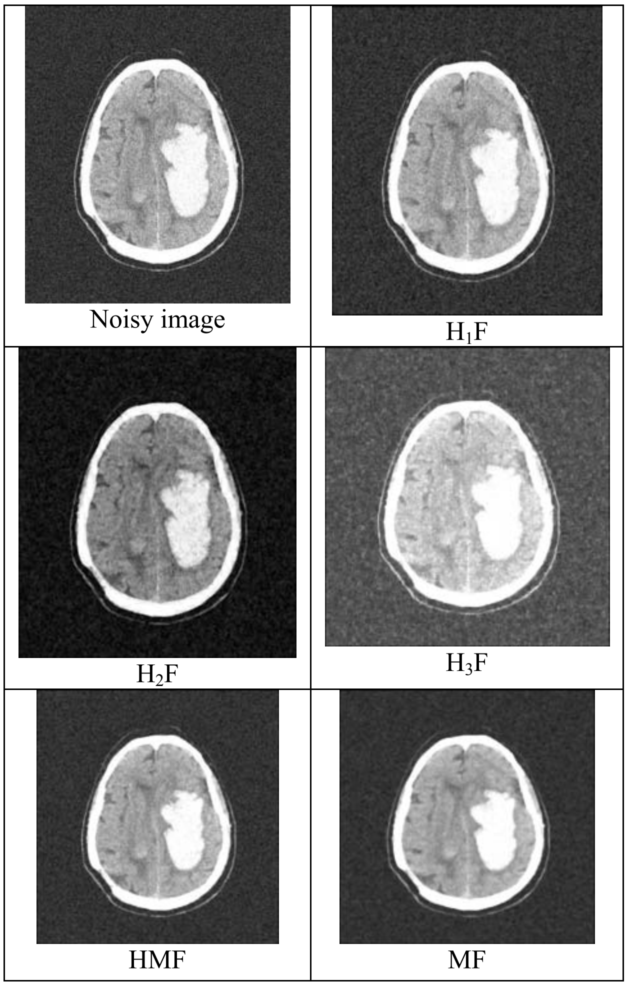


Figure-1

REFERENCES

[1] R. Gonzalez and R. Woods. 1992. Digital Image Processing. Adison -Wesley, New York.

[2] H. Hu and G. de Haan. 2006. Classification-based hybrid filters for image processing. Proc. SPIE, Visual Communications and Image Processing. 6077, 607711.1-607711.10.

[3] Hakan Güray Senel, Richard Alan Peters and Benoit Dawant. 2002. Topological Median Filter. IEEE Trans on Image Processing. 11(2): 89-104.

ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

[4] http://www.librow.com/articles/article-8.

[5] Ioannis Pitas, Anastasias N Venetsanopoulos. 1990. Nonlinear Digital Filters: Principles and Applications. NJ: Springer Publisher.

[6] Klaus Rank and Rolf Unbehauen. 1992. An Adaptive Recursive 2-D Filter for Removal of Gaussian Noise in Images. IEEE Transactions on Image Processing: 431-436.

[7] Mamta Juneja and Rajni Mohana. 2009. An Improved Adaptive Median Filtering Method for Impulse Noise Detection. International Journal of Recent Trends in Engineering. 1(1): 274-278.

[8] S. Peng and L. Lucke. 1995. A hybrid filter for image enhancement. Proc. of International Conference on Image Processing (ICIP). 1: 163-166.

[9] Rosenfeld. 1979. Digital topology. Amer. Math. Monthly. 86: 621-630.

[10] Salem Saleh Al-amri, N.V. Kalyankar and Khamitkar S.D. 2010. A Comparative Study of Removal Noise from Remote Sensing Image. International Journal of Comp. Science. 7(1): 32-36.

[11] R. Sivakumar. 2007. Denoising of Computer Tomography images using curvelet transform. ARPN Journal of Engineering and Applied Sciences. 2(1): 21-26.

[12] J. W. Tukey. 1974. Nonlinear (nonsuperposable) methods for smoothing data. In: Proc. Congr. Rec. EASCOM ’74. pp. 673-681.

[13] Yanchun Wang, Dequn Liang, Heng Ma and Yan Wang. 2006. An Algorithm for Image Denoising Based on Mixed Filter. Proceedings of the 6th World Congress on Intelligent Control and Automation. June 21-23. pp. 9690-9693.