Research Paper

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Survey on Spatial Filtering Techniques

Engineering

KEYWORDS : image denoising, spatial domain filter, impulse noise, salt and pepper noise

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ABSTRACT

An image is the collection of information, which is acquired from digital cameras and the noise present in images causes degradation in the quality of images. Noise removal plays vital role for all kinds of noises since it becomes very important preprocessing task for carrying out further post image processing like image segmentation, image compression etc. Noises are introduced into the image during image acquisition from cameras, Transmission error cause, and due to motion and out of focus problem in the cameras, hazy weather, Atmospheric turbulence and also due to sensors etc. Thus it is mandatory to remove all kinds of noises for effective image restoration and enhancement. Many challenging algorithms were developed confining to spatial domain. This paper elucidates many filtering algorithms with their merits and demerits in detail and discussions and conclusion were made elaborately by reviewing different algorithms from scratch level to recent development. Spatial denoising methods are the one where the pixel intensities are used directly in the denoising process. This survey paper mainly focuses on filtering algorithms which exploits spatial domain filtering process.

INTRODUCTION

Digital images plays vital role in day to day applications. Noise is introduced in the images during transmission and acquiring from cameras. Any unwanted signal and its electrical interference and blur due to camera movement, environmental conditions like rain, snow, and sampling and quantization errors could be considered as noise. In other terms one person's signal might be another person's noise. The noise complicates the post process of compression and other image processing tasks. So it becomes very essential to remove noise for better interpretation by human eyes.

There are two types of noise namely multiplicative noise and additive noise [1]. The multiplicative noise is generally complex model and caused by de-phased echo signals from scatters. It is image dependent and difficult to reduce noise though it contains useful information.

There are other kinds of noise called additive noise which is systematic and easy to model and noise can be removed with less effort.

An additive noise model represents as

$z(x, y) = s(x, y) + n(x, y)$,

The multiplicative noise satisfies

$z(x, y) = s(x, y) \times n(x, y)$

where $s(x,y)$ is the original signal information, $n(x,y)$ represents the noise introduced into the signal and the output produced the corrupted image $z(x,y)$, and (x,y) represents the pixel location[1]. Image addition finds applications in image morphing.

The multiplication alters the brightness of the image.

The denoising is an operation to estimate clean image from a degraded or noise affected image and this process is required to achieve visually pleasant and also to get quality reconstruction of image. The basic filtering methods are classified into spatial domain method and Transform domain method. This paper mainly focuses on the significant progress made on spatial domain filtering approach and not considering transform domain methods. It is well known that denoising filers are broadly classified into linear filters and non linear filters. This paper aims to present survey of both types of filters.

SALT AND PEPPER NOISE

Salt and pepper noise is a fixed impulse type of noise, which is also referred as intensity spikes. This is caused due to errors in transmission of digital data. It has two possible values, 0 and 255. The probability of each is typically less than 0.1. The noisy pixels are set either to the minimum or to the maximum value. It then shows the image a "salt and pepper" like appearance, whereas the other unaffected pixels remain intact. For an 8-bit image, the typical value for pepper noise is 0 and for salt noise 255. The salt and pepper noise is also caused by improper functioning of pixel elements in the camera sensors, faulty memory locations, or timing errors in the

Sampling and quantization process [2]. Figure1 shows the appearance of salt and pepper noise in image.

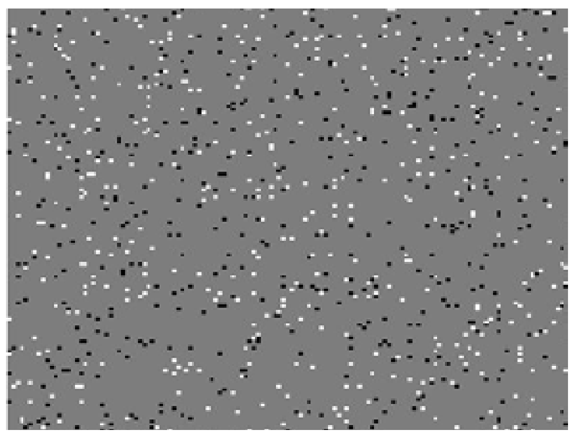

Figure1: salt and pepper noise
Sources: www.googleimages .com

NOISE MODEL

If x tends to be the original image and n is its noise then the corrupted image y=x+n, then the reconstructed image is given by = y –

Impulse noise model for fixed impulse noise is as follows [3].

Y(i,j)=255 with probability of P/2
0 with probability of P/2
X(i,j) with probability of 1-P

LINEAR FILTERS

Generally the filtering process is understood as a neighborhood operation and the linear filtering is the filtering in which the value of an output pixel is a linear weighted combination of the values of the pixels in the input pixel's neighborhood. Moreover the Linear filter is a moving window spatial filter in which the centre pixel value of the window is replaced by the average of all neighboring pixel values. The key concept exploited in linear filtering is either based on convolution or sliding window process.

The basic linear filters such as Low Pass Filter(LPF) averages small fluctuations in the image intensity values and it is meant for random noise suppression and smoothing but it tends to image fading by blurring of edges. This problem can be rectified using High Pass Filters by enhancing details and emphasizing edges but at the cost of increasing noise information. The Gradient directional filter could retain fine structures and Laplace filter improves image sharpness and enhancing details but a tradeoff between degrees of smoothness to edge preservation still exists.

The merits of linear filters are that it has speed in computation, ease of operation and simplicity. One of the linear filter which employs averaging of pixels is called mean filter. Supposing if intensity pixel values of range P1 to Pn, then the linear filtering output as

The mean filter finds its applications in photographic grain noise removal. Including this these filters find applications which are limited in certain part of the image denoising and not for entire image.

The demerits of linear filters are the following

- It is not suitable for non-additive noises
- It introduces blurring-effect if degree of denoising increases.
- It is not efficient for removing impulse noise since each and every pixel is processed and replaced by median thus it tends to alter non corrupted pixels also.
- It is not preserving edges.
- A tradeoff between computation complexity and the amount of denoising
- Constant weight matrix offered
- Impulse noise is diffused but not removed
- Ringing introduces additional noise

There are many types of mean filters such as Arithmetic,Geometri,Harmonic and Contra harmonic mean filter etc..

Arithmetic mean filter tends to averaging pixels and smoothes variation and reduces noise.

Geometric mean filter tends to perform geometric mean instead ordinary mean and preserve more details by reducing loss of details than arithmetic mean filter, and Harmonic filter tends to perform harmonic mean and works better for Gaussian and salt noise but poor for pepper noise.

Contra harmonic filter based on the Q order of the filter in which Q+ for pepper noise Q- for salt noise ,Q=0 for arithmetic mean filter and Q=-1 for harmonic mean filter and so on. These filters cannot remove both salt and pepper noises simultaneously. The problems with all the above filters are that those are performing denoising well but not preserving edges [4].

One more filter in the linear domain was introduced that is known as the wiener filter, which is again a linear filter and works based on statistical approach but it requires information about spectra of both original image and noise. It is better for periodic noise, poisson noise and speckle noise removal but it is not recommended for salt and pepper denoising,

Another idea of introducing weights for the coefficients based on the pixel value came. With this idea, the Gaussian filter is showcased, which is a kind of linear filter which exploits weights for the pixels. More weights assigned for edge pixel and the degree of smoothing could be controlled by σ increment [5, 6].

Further extended idea of weight matrix variation was proposed to an adaptive filter, which is somewhat better than linear average filter, since it could be applied for non stationary images and weight matrix could be made variable after each iteration [7].

The consequence of this adaptive filter came and is known as Least Mean Square Adaptive filter showcases still better performance in computation and implementation wise and one can get residual matrix out of it for better analysis of performance.

NON LINEAR FILTERS

The non linear filters which are used for impulse denoising are median filters. These filters are widely used filters and are based on median value. The various types of median based filters are SMF (Standard Medium Filter), AMF (Adaptive Medium Filter) and decision based medium filter etc. Non linear filters based on order statistics or ranking are Minimum, Median, Maximum, Midpoint and Alpha trimmed filters are better for low density noise removal but exhibits blurring for high noise density. Each filter has its own merits and demerits [8].

The Minimum filter is used to reduce salt noise and to find dark spots in the image, since the pixel under consideration is replaced by minimum value of neighborhood pixels [8].

The Maximum filter is employed to reduce pepper noise and to search bright spots in the image, since the pixel under consideration is replaced by maximum value of neighborhood pixels [9].

The Midpoint filter replaces midpoint average of maximum and minimum value of neighborhood pixels. It works better only for the random noises like Gaussian or uniform noise.

Alpha trimmed filters trim lowest and highest values of pixels and the other remaining pixels median value is used for replacing noisy pixel. This filter is better for combined salt, pepper and Gaussian noises [11].

The Standard Median Filter (SMF) in which median value could be computed as below [9].

If x1, x2, x3….xn are the intensity values in a window and these values are sorted either in the ascending order or in the descending order in such a way that xi1 ≥ xi2 ≥ xi3…….≥ xin then the xmedian = Med{xi} = xi(n+1)/2 if nis odd and ½{xi(n/2)+xi(n/2)+1 if n is even.

The non linear median filter is more robust when compared to the Linear mean filter,Since the median value actually the one among the neighborhood pixels and the median filter does not create new unrealistic pixel or no pixel other than window pixel values. For this reason the median filter is much better at preserving sharp edges than the mean filter. These advantages aid median filters in denoising uniform noise as well from an image.

SMF proved its excellence only for low noise density removal of impulse noise and preserves the edges as well. But if window size or noise density increases it exhibits blurring and also insufficient noise suppression for small size windows. Moreover this filtering technique alters non-noisy values present in the image since most of the median filters operate uniformly across the image. It is not an appropriate filter for Gaussian and speckle noise removal. It has a demerit of complex computation since more comparison and sorting is required and in turn results expensive process [10].

Impulse noise detection is challenging than filtering, since impulse noise is of two types known as fixed impulse noise and random valued impulse noise. Detecting fixed impulse noise is easy and many filtering algorithms were proposed, but detection of random valued impulse noise is too tough and challenging because the pixel intensity value lies between 0 and 255 and can possesses either edge information (or) noise.

So the detection process has a wide opening for researches in the image processing community and for particularly denoising tasks. Researchers have started noise detection process before filtering. In this motive many filters came and are classified as adaptive median filters, decision based median filters and switching median filters etc.

In adaptive median filtering, the window size is adaptive to noise density level and it is good only at low density noise level. Since increasing window size though it provides better noise removal but it smears edges [13].

In both the Decision based and switching based median filters, the decision measure is difficult and in addition to that the details and edges are not recovered satisfactory for high level noise density. Moreover decision based filters even though replaces neighborhood pixel for fixed impulse noises, it introduces streaking effect [11, 12].

One more effort based on decision measure called Desion Based Unsymmetric Trimmed Median Filter(DBUTMF) in which trimmed median value is replaced, if the selected moving window elements are comprised of 0 and 255.The limitation here is trimmed median cannot be obtained and results are poor for the noise density greater than 80%[11].

To overcome the above problem symmetrical trimming approach was proposed where trimming is performed at both ends by exploiting Alpha Trimmed Mean filter. Disadvantage of this is it trims uncorrupted pixels too which in turn leads to loss of important image details and results blurring effect. In view of this drawback, it was suggested as remedy that Unsymmetric Trimmed Median Filter (UTMF) was performed so that this method sorts all the elements in ascending or descending order, and in that order the noisy pixels are removed first and then the remaining pixels alone are considered for taking median value and the same is replaced [11].

The modification and solution for all of the above approaches was proposed by Esakkirajan et al.,known as Modified Decision Based Unsymmetric Trimmed Median Filter(MDBUTMF),claiming that the detection is first carried out. The two extreme values (0 and 255) are detected as noisy values, and in between 0 and 255 values are treated as noise free pixels. If all the pixels in a selected window composed of 0 and 255 then the centre pixel under consideration is replaced by the mean of the window. Else, wherever 0 and 255 presents shall be eliminated and the remaining pixels alone after elimination are considered for calculating median value [11].

The limitation of switching based median filters are that these filters are non adaptive to noise density variation and misclassifying pixel characteristics at high density noise interference. The alternate remedy for this technique is proposed by How-Lung, one efficient algorithm for noise adaptive soft switching median filter for detection and filtering scheme was proposed, which is meant for classifying the pixels into four categories 1.uncorrupted pixel in which no filtering is applied 2.Isolated impulse noise in which median filter is applied 3.Non isolated or edge pixel in which FWM (Fuzzy Weighted Median) filter[10] is applied to identify the pixel under consideration as either edge pixel or noise pixel. In this technique small window size is offered for low density noise level and large window size is offered for high density noise level and in addition to this greater weight could be assigned for closely correlated pixels and lesser weights for less correlated pixels.

To overcome all the above said problems the two phase algorithm has been proposed by Srinivasan and Ebenezer. In the first phase, adaptive medium filter is used to classify (or) detect the nature of pixel, ie either corrupted or uncorrupted pixel and in the second phase special regularization method is employed only for noisy pixels to preserve the edges. This two phase algorithm processing time is more due to selection of very large size window of range 39x39 for both phases to get optimum result. It has added drawback of more complex circuitry and difficulty for the determination of smoothing factor β.

To overcome the above problem of complexity, a new replace approach has been adopted instead of conventional median value replacement for corrupted pixel, here exploits neighborhood pixel itself for replacement unlike AMF and other filters which uses only median value. It is well known that particularly at the higher level noise density, there are situations that the median value itself might be noisy value after applying filtering. In that time the centre pixel would be replaced with the neighborhood pixel, thereby edge could be preserved which in turn reduces computational complexity. Moreover this paper exploits 3x3 windows only which yields lower processing time than AMF and other filters.

In order to overcome computational complexity and hardware complexity and also to improve speed of operation, one modified method [23]of sorting has been implemented by the author Rajamani et al., that is known as LDS(Lone Diagonal Sorting)algorithm in which three right diagonal elements only were taken for sorting and median value of three elements were carried out instead of nine pixel sorting as in traditional approach. The advantage of this technique could be the number of sorting is very less so that computational complexity is reduced in a significant manner. The disadvantage is that it will treat all pixels equally and there is no measure of detection of noisy pixel prior to filtering.

One more approach was proposed by Irphan Ali Shaik et al., which is by improving impulse detection using Adaptive switched median filter which is based on normalized absolute difference and exploiting the different filters like TSM(Tri State Median),PWMAD(Pixel wise MAD),CWM(Centre Weighted Median) etc.This paper proposes a new IID (Improved Impulse Detection) for the random valued noise since the standard median filter is not suitable for random valued noise[10-16].

From here onwards the researchers are much attracted by the detection and removal of random valued impulse noise. From this objective the authors Yiqiu Dong and Shufang Xu have proposed a new DWM(Directional Weighted Median filter).It overcomes the performances of other filters like ALM(Median filters with adaptive length,MSM(MultiState Median,ACWM(Adaptive Centre Weighted Median) and SD-ROM(Signal Dependent Rank Order Mean)filter etc.This paper has chosen four directions with respect to centre pixel which is the pixel under consideration. The absolute difference between centre pixel to directional pixels are considered for all four directions[18]. The pixel difference which offers minimum value claims non noisy since those were closer values and are weighted with two and finally all weighted pixels are added. The same above said treatment is given for all directions. The direction which gives minimum value could be treated as non noisy and large value could be treated as noisy and if any one of the direction offers minimum means it could be treated as edge pixel.

The limitation of the above DWM method is that it leaves some of the pixels intact. This could be further improved by considering more directions and all neighborhood pixels in near future work [18].

Some of the works were carried out on real time scanned images which was taken from engineering drawings, which are actually binary images with salt and pepper noise. For removal of noise the median filter presents distortion of corners and thin lines in turn results edge blurring effect and one more method using morphological filters also fails since it has a drawback of thin line removal due to graphical elements merge with close ones[2, 19].

The another filter for noise removal from document images is the KFill filter and shows disadvantage as it shortens blobs connected to graphical elements but not trying to remove it. For this problem the author Hasan et al., used CWM (Centre Weighted Median filter) in which the centre pixel of the selected window is given more weight than the other neighborhood pixels. So this approach could retain fine details of the image [2, 19-22].

RESULTS AND DISCUSSION

The quantitative analysis of various filters are given in view of the metric PSNR(Peak Signal to Noise Ratio) for the gray scale image.Table1 shows the PSNR values for various linear and non linear filters and Figure 1 shows the graph of the same. From the results it is inferred that the non linear filters like median based filters presents promising results than all linear based filters and it has been proved quantitatively.Table1 and Figure 2 shows the comparison of PSNR of various filters.

TABLE - 1
RESULTS FOR SALT AND PEPPER NOISE REMOVAL

Name of the filter	PSNR value
Arithmetic mean Filter	23.75
Geometric mean filter	24.47
Harmonic filter	14.41
Contra harmonic filter	21.04
Median filter	25.25
LDS (Lone Diagonal Sort)algorithm	26.71
Minimum Filter	19.32
Maximum Filter	0

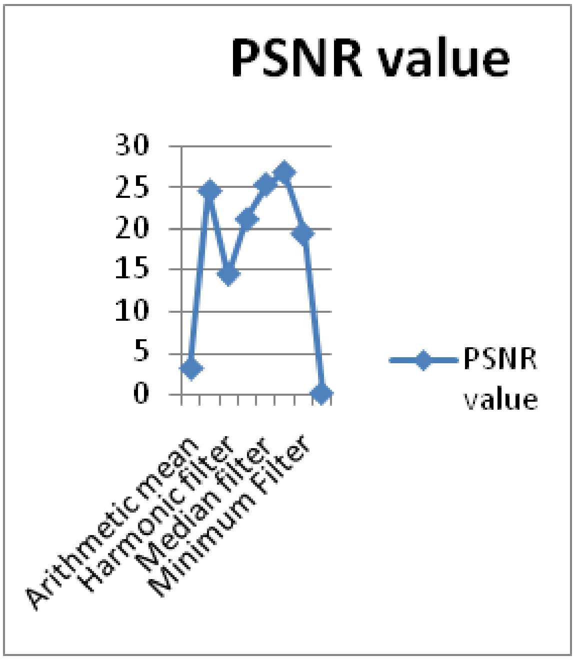

Figure2: graph of PSNR of various filters

CONCLUSIONS

This survey paper summarizes various linear and nonlinear filters with its own merits and demerits in the denoising approach confined for the removal of salt and pepper noise. This paper also covers impulse noise of random valued type. This work further could be extended for the progress done on the impulse detection domain rather than filtering algorithm domain since almost filtering process techniques gets almost saturated particularly in fixed impulse noise. But still there is wide opening in frequency domain new techniques. Future work may be extended confined to Random valued impulse noise detection and removal.

REFERENCE

[1] Rupinderpal Kaur and Rajneet Kaur, (2013)," Survey of De-noising Methods Using Filters and Fast Wavelet Transform,"International Journal of Advanced Research in Computer Science and Software Engineering, Vol.3,Issue 2. | [2] Abdul Salam, (2008),"Removing Salt-and-Pepper Noise from Binary Images of Engg Drawings"IEEE. | | [3] Hanji,G., and Latte,M.V.(2012), "A New Impulse Noise Detection and Filtering Algorithm", International Journal of Scientific Research and Publications, Vol. 2, Issue 1. | | [4] Rafael C Gonzalez,Richard E Woods,(2009),"Digital Image Processing",Pearson Prentice ,3rd Ed. | | [5] Vijay Kumar, V.R., Manikandan,S., Vanathi,P.T., Kanagasabapathy,P. and Ebenezer,D."Adaptive Window Length Recursive Weighted Median Filter for Removing Impulse Noise in Images with Details Preservation", ECTI Transactions on Electrical Eng., Electronics, and Communications, Vol.6, No.1 | | [6] Raymond H.Chan,Chung-Wa Ho,and Mila Nikolova,(2005),"Salt-and-pepper Noise Removal by Median-Type Noise Detectors and Detail-Preserving Regularization,IEEE Transactions in Image Processing,Vol.14,Issue 4. | | [7]AliShaik,Mirza shafi shansavar, SilvaLorraine,Ajesh Kumar, K.J., vishwanadham and Mahender Raju T.,(2012),"Impulse noise detection and filtering based on Adaptive Weighted Median Filter",International Journal of Engg and Science,Vol.1,Issue 8. | | [8] Geoffrine, J.M.C.and Kumarasabapathy N.,(2011), "Study And Analysis Of Impulse Noise Reduction Filters", Signal & Image Processing: An International Journal (SIPIJ), Vol.2, No.1. | [9] Srinivasan , K.S. and Ebenezer,D, (2007),"A New Fast Efficient Decision –Based Algorithm for Removal of High-density Impulse noises",IEEE signal processing letters,V ol.14,Issue 3. | | [10] How-Lung and Kai-Kuang Ma,(2001),"Noise Adaptive Soft Switching Median Filter', IEEE Transactions in Image Processing,Vol.10,Issue 2. | | [11] Shekar,D and Srikanth, R.,(2011),"Removal of High Density Salt & Pepper Noise in Noisy Images Using Decision Based UnSymmetric Trimmed Median Filter (DBUTM)", International Journal of Computer Trends and Technology, vol. 2, Issue 1. | [12]ShuQun Zhang and Karim A.,(2002),"A New Impulse Detector for Switching Median Filters", IEEE signal processing Letters,Vol.9,Issue11. | | [13]Hwang H. and Haddad, R. A., (1995),"Adaptive Median Filters: New Algorithms and Results", IEEE Transactions on Image Processing, Vol. 4, No.4. | | [14]Gebreyohannes,T.,and Dong-Yoon,K.(2011), "Adaptive Noise Reduction Scheme for Salt and Pepper", Signal & Image Processing: An International Journal, Vol. 2 Issue 4, p47. | | [15] Jayaraj, V., Ebenezer, D.and Aiswarya, K. (2009), "High Density Salt and Pepper Noise Removal in Images using Improved Adaptive Statistics Estimation Filter", International Journal of Computer Science and Network Security, Vol.9 No.11. | | [16] Pomalaza-Racz, C. A. and Macgillem, C. D.(1984), "An adaptive non linear edge preserving filter," IEEE Trans. Acoust., Speech, Signal Process.,vol. ASSP-32, 571–576. | | [17]"An Improved Weighted Median Filter for the Image Processing Application" (2013), International Journal of Science and Research, Vol.2 Issue.4. | | [18] Dong and Shufang Xu,(2007),"A New Directional Weighted Median Filter for Removal of Random-Valued Impulse noise",IEEE signal processing letters,Vol.14,Issue 3. | | [19] Sun T. and Neuvo Y., (1994),"Detail-preserving median based filters in image processing," Pattern Recognit. Lett., vol. 15, 341–347. | | [20] Eng H.-L. and Ma, K.-K.(2001), "Noise adaptive soft-switching median filter,"IEEE Trans. Image Process., vol. 10, no. 2, 242–251. | | [21] Pok, G. and Liu J.-C.,(1999), "Decision based median filter improved by predictions," in Proc. ICIP, vol.2,410–413. | | [22] Florencio, D.and Schafer, T. (1994),"Decision-based median filter using local signal statistics," in Proc. SPIE Int. Symp. Visual Communications Image Processing, Chicago, IL. | | [23] Rajamani A,Krishnaveni V,WassimFerose.H and Kalaikamal M.,(2012),"A New Denoising Approach for the Removal of Impulse Noise from Color Images and Video Sequences,"International Journal of Image Analysis and Streology,Vol.31,No.3. |