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A Review of Decision Based Impulse Noise Removing Algorithms

SnehalAmbulkar*, PritiGolar**
*(Department of Computer Science & Engineering, St. Vincent Pallotti College of Engineering & Technology, R.T.M. Nagpur University,India)
**(Department of Computer Science & Engineering, St. Vincent Pallotti College of Engineering & Technology,R.T.M. Nagpur University, India)

***Abstract*—**Noises is an unwanted factor in digital image and videos, hiding the details and destroying image information. Hence denoising has great importance to restore the details and to improve the quality measures. This paper takes a look towards different type of noise found in digital images, Denoising domains, and classification of denoising filters. Some denoising filters like Median filter (MF), Adaptive median filter (AMF) and simple adaptive median filters (SAMF) are described and compared briefly. A new approach is proposed for video denoising using combination of median filters with multiple views.
***Keywords*—**Adaptive Filter, Denoising, Impulse noise, Median filter, Salt-and–pepper, Switching Median Filter

I. INTRODUCTION

Digital Images or image sequence also called as video is getting very much importance in day to day lives. It is highly important to obtain and maintain the quality of images and/or video at an acceptable level in various application environments such as network visual communications. One of the most promising applications of digital video is in the area of medical diagnosis where the videos or images ofinner body structure are complex and needs minute details with clarity.

Image sequences are often corrupted by noise, e.g., due to bad reception of signals over channel through which they are transmitting. Some noise sources are located in sensor of a camera and become active during image acquisition under bad lightning conditions. Other noise sources are due to transmission over analogue channels and thus need to use analog to digital converter which also leads to noise contamination. In most cases the noise is white and Gaussian, and in some cases low-level impulse noise. Noise reduction in image sequences is used for various purposes, e.g. for visual improvement in video surveillance [1]. It is achieved through effective video denoising algorithms that can remove or reduce the noise is often desired. They not only supply video signals that have better perceptual quality, but also help improve the performance of the subsequent processes such as compression, segmentation, resizing, de-interlacing, and object detection, recognition, and tracking [2].

II. LITERATURE SURVEY

Lots of image denoising algorithms were developed in the past years in the search of better result generating algorithm which not only improves the image quality but also preserves the minute image details and helps to enhance the quality of digital image. These denoising technics are performed in spatial or transform domain [3]. The most popular and conventional filter in spatial domain for Salt-and-pepper noise is median filter[4]. This filter is simple and has capability of edge preservation [5]. Since this filter process both "*Noisy*" and "*Noise Free*" pixels the resultant image results in blurring, distortion and loss of lines and corners. This is the reason for variation and improvements in median filters.

Adaptive median filter[3]with flexiblefilterwindow size was introduced to minimize the blurring effect. For further reducing the blurring effect weight allotment concept was introduced. In Weighted median filter[6], Center weighted median filter (CWMF) [5], Recursive weighted median filter [7] some specific pixels in filtering window were assigned with more weight.

In [8], A new kind of adaptive weighted median filter was proposed which uses the block uniformity as standard for testing to detect the impulse noise on the image. This filter alleviates the conflict between the noise restraint and the image detail reservation to great extent and hence has better integrated filtering performance than both the standard median filter and the adaptive median filter.
An Adaptive center weighted median filter (ACWM) was proposed in [9], which uses an efficient scalar quantization (SQ) method to partition the observation vector space and obtain the optimal weight for each block. Whereas to extract centre weight within each block a least mean square (LMS) learning algorithm is used. This algorithm removes the drawback of both CWMF and switching median filter.

Switching median filter is a framework which adopts noise detection approach. A tri-state median algorithm [10] is a switching median filter which combines both CWMF and standard median filter to replace the noisy pixel.

A modified adaptive center weighted median filter (MACWM) was proposed in [11] which obtain the adjustable central weight by partitioning the observation vector space using fuzzy clustering technique.

In [12], a new adaptive center-weighted hybrid mean and median filter was formulated and used within a novel optimal-size windowing framework to reduce the effects of sensor noise.A Stuck–pixel filter is another concept introduced toremove stuck–pixel noise occurred due to long-exposure of images.

III. TYPES OF NOISE

Noise is unwanted information which affects the original information in the image and leads to quality deterioration. Image acquisition is the major source of noise in digital images due to hardware condition of CCD camera i.e sensor quality and response to environmental conditions such as light level. Noise has individual properties in both spatial as well as frequency domain. When Fourier spectrum of noise in frequency domain is constant then the noise is called as White Noise.

Gaussian noise, also called as Natural noise is generally found in acquisition of nature imageswhich lead due to standard deviation in pixel values. This noise is a resultant of factors such as electronic circuit and sensor noise due to poor illumination and/or high temperature [3]. Illumination leads to statistical variation in number of photons on sensor surface so called as photon noise. Dark Noise is generated due to electrons generated within the sensor due to thermal act. This noise is proportional to square root of number of electrons generated [13].

Image acquisition through camera leads to unstable voltage which causes Impulse noise, also called as Salt-and–pepper noise. It deals with the probability of finding only two intensity values i.e. minimum and maximum. This makes image consisting of black and white spot hence called as Shot and Spike noise.

IV. CLASSIFICATION OF IMAGE DENOISING ALGORITHMS

Basically image denoising algorithms are mainly classified into two categories- Spatial Domain Filtering and Transform Domain Filtering.

A. Spatial Domain Filtering

Traditionally noise removal was done by manipulating the gray level pixel values, which is called as spatial domain filtering. Algorithms fall in this category are distributed in two pars i.e. Linear Filters and Non-Linear filters.

Linear filters result into the average weighted sum of products of the mask coefficients with the corresponding pixels of input image directly under the mask. Whereas non-linear filtering operations replace the pixel values of input image depending upon conditions applied on the pixel values in the neighborhood under consideration.

Non-linear filters don't go for noise detection policy and processing of noise free pixels carried away. This filters assume that higher region of frequency spectrum consist of more noise contamination and hence undergoes low pass filtering. For Gaussian noise removal the optimal linear filter is Mean Filter depending on mean square error (MSE). On the contradiction it gives the bad performance in the presence of Signal dependent noise.

Spatial filters are effective in denoising to a deep extent but fail to preserve details like sharp edges, which lead to image blurring and loss of fine details. To overcome this drawback many algorithms were proposed in the recent years like weighted median filters [6], rank conditioned rank selection [14], and relaxed median [15]. These are examples of non-linear filters. In linear spatial domain Wiener Filtering [16] complexity regarding window size selection result into the development of Wavelet based filters [17].

B. Transform Domain Filtering

Transform domain filtering techniques are categorized depending upon the choice of basis functions. This basis function are further subdivided into two categories [18] –

a) Non-data Adaptive transform
b) Data Adaptive transform

Non-data adaptive transform filters are more popular denoising technique which are consist of spatial frequency Domain filtering and Wavelet Domain filtering.

Spatial frequency Domain filtering uses low pass filtering using Fast Fourier Transform. Wavelet Domain filters are subdivided into– Linear filtering, Non-Linear threshold filtering, Wavelet coefficient model and Non-Orthogonal Wavelet transform.

Independent Component analysis (ICA) [19] is a new method in Data-Adaptive transform techniques which grabs the attention in denoising Non-Gaussian data.

V. MEDIAN FILTER

Median filtering (MF) [3] is an effective and well known non-linear order statistic filter in removing impulsive noise. Impulsive noise is basically defined as a set of strong spike like components which drastically differs in intensity values form neighborhood region of pixel.

As it is an order statistic filter, it replaces the pixel value of original image by the median of sorted intensity values in considered neighborhood pixel region.

Algorithm:

$$\hat{f}(x,y) = \underset{(s,t)\in Sxy}{median}\{g(s,t)\} \quad \ldots(1)$$

Following are the computational steps in median filters:

1. Let*f* be a monochrome (1-band) image.
2. Let S define a neighborhood/filter window of square shape where g(s,t) is pixel belonging to it.
3. At each pixel location, p = *f*(x,y) in *f*.
4. Select the *n* pixels in the S-neighborhood of p.
5. Sort the selected *n* pixels in the neighborhoodof p.
6. The output value at p is$\left\lfloor\frac{n}{2}\right\rfloor + 1$. [3]

Median filters are better enough to suppress certain noise type and results into less blurring than Mean filters. They preserve the step edges better than smoothing filters.

Drawback:

Though this filter is simple and popular, they lack in detail preservation and noise reduction simultaneously. As impulse noise density increases the quality of resultant image falls down. Median filter suppresses the noise effectively but at the cost of image distortion and blurring since it consider all the pixels for processing within a fixed filter size.

VI. ADAPTIVE MEDIAN FILTER

Median filter performance is not effective as high impulse noise density is considered, to improve this drawback an Adaptive median filter (AMF) [20] with variable window size adaptable to local noise contain was developed.

In order to effectively preserve the details of image while suppressing noise, pixels with low noise level contamination are filtered using small size filtering window. On the contrary for better noise suppression atpixel locations with high noise level contamination large size filtering window is applied.

Algorithm:

1. $A1 = Z_{med} - Z_{min}$ and
   $A2 = Z_{med} - Z_{max}$
2. If A1> 0 AND A2<0, go to step 4
   Else $W = W + 2$
3. IF $W \leq W_{max}$, go to step 1
   Else output Z_{xy} at P(x,y)
4. $B1 = Z_{xy} - Z_{min}$ and
   $B2 = Z_{xy} - Z_{max}$
5. IF B1> 0 AND B2 < 0, Output Z_{xy}
   Else Output Z_{med} at P(x,y)

Where,
W= Window Size
W_{max} = Maximum allowed size of Window
Z_{min} = Minimum gray level value in Window
Z_{max} = Maximum gray level value in Window
Z_{med} = Median values of gray levels in window
Z_{xy} = Gray level at pixel location P(x,y)

In this algorithm, Variation in window size tacks place till correct median value is not obtained, which will replace the noisy pixel, or till window size reach its maximum limit. The algorithm results in output value Z_{med} when it reaches to maximum window size.

Drawback:

This filter puts the limitation on filtering window size. As it reaches to maximum window size it outputs a median value which does not provide a guarantee of weather this value is impulse or not.

VII. SWITCHING MEDIAN FILTER

The median value calculations and replacement of pixels in conventional median filtering are independent of whether pixels are noisy or not. This makes the resultant image with detail distortion. Switching median filtering (SMF) [21] overcomes this drawback by implementing decision making process in the filtering framework. Adaptive median filter and standard median filters are based on homogeneity information and so called as decision based or switching filters.

This Filtering technique is result of two stages: Noise detection and noise removal. Classification of the pixels into “Noise contaminated” and “Noise Free” are performed on the basis of image attributes like gray level intensity values. Whereas removing of noise takes palace using Median Filter technique.

Since median filter uses fixed window filter size it is quite difficult to find correct value of median which is close to real pixel value in original image.

VIII. SIMPLE ADAPTIVE MEDIAN FILTERS

Simple adaptive median filter (SAMF) [22] is hybrid filter developed by combining the features of Adaptive median filter and switching median filter. Adaptive median filter provides flexibility of adapting variable size of filtering window according to local noise level in an image. Whereas switching median filter speeds up the process by ignoring the noise free pixels while processing. The combination of these twofeatures makes Simple adaptive median filter more powerful.

This filter consists of two basic steps:

a) Finding Noisy Pixels
b) Noise Removal

A) Finding Noisy Pixel

For impulse noise detection the two intensity levels i.e minimum and maximum are considered to be noisy whereas others are considered as noisy free. Let L be the number of intensity levels present in an image then 0 and $L-1$ are the minimum and maximum intensity value respectively considered as noise contaminated pixels which may create Black and white dots in an image.

i) As per intensity values create a mask $\alpha(x,y)$ to detect whether the pixel is noisy or noise free using conditional equation:

$$\alpha(x,y)=\begin{cases}1 & : f(x,y)=0\\ 1 & : f(x,y)=L-1\\ 0 & : Otherwise\end{cases} \quad \ldots (2)$$

Where 1 indicates the "Noisy Pixel" and 0 indicates "Noise Free Pixel".

ii) After pixel classification to detect local noise density in an image calculate the number of noisy pixel (K) is given by

$$K=\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}\alpha(x,y) \quad \ldots (3)$$

iii) Calculate the number of"Noise Free Pixels" (P_n) as follows

$$P_n=(MN)-K \ldots (4)$$

Where, $M\times N$ is a size of image ($W_{M\times N}$).

iv) Estimation of rough noise density (η) takes a ratio of the noisy pixel to the total number of pixels in image.

$$\eta=\frac{K}{(M/N)} \quad \ldots (5)$$

Value of η is always between 0 and 1 i.e. $0\le\eta\le1$.

B) Noise Removal

Similar to switching median filter output, Simple adaptive median filter output is defined as:

$$g(x,y)=[1-\alpha(x,y)]f(x,y)+\alpha(x,y)m(x,y) \quad \ldots (6)$$

Where $g(x,y)$ is a filtered output of corrupted image $f(x,y)$.

The output $g(x,y)$ is either having value $f(x,y)$ or $m(x,y)$ this is because of mask $\alpha(x,y)$ which consist of only two values 0 and 1. Hence $g(x,y)$ can re-write as:

$$g(x,y)=\begin{cases}f(x,y) & : \alpha(x,y)=0\\ m(x,y) & : \text{otherwise}\end{cases} \quad \ldots (7)$$

Where, a median value $m(x,y)$ with consideration of Noise-Free pixels is calculated using adaptive median filter.

For median value calculation using adaptive median filters an odd size filter window $W_{M\times N}$ is calculated as

$$W=W_M=W_N=2R_{min}+1 \quad \ldots (8)$$

Where R_{min} is a positive integer value calculated as:

$$R_{min}=\frac{1}{2}\sqrt{\frac{7}{(1-\eta)}} \quad \ldots (9)$$

To determine $m(x,y)$ following set of rules are defined.

Algorithm:

For each noisy pixel location (x,y) with $\alpha(x,y)=1$ do:

1. Initialize the filter window size $W_{M\times N}$ with eq^n (8), (9).
2. Compute K using eq^n (3) for region defined by window size initialized in step 1.
3. If number of "Noise free pixels" P_n by eq^n (4) is less than eight pixels,
   Then increase window size as:
   $$W=W+2$$
   And return to step 2.
4. Calculate the value of $m(x,y)$ depending upon the Noise free pixels present in considered window size. This means the median intensity value of noise free pixels in given window size.
5. Update the value of $g(x,y)$ using either eq^n (6) or eq^n (7).

Here calculation of the median value $m(x,y)$ depends on the noise free pixels and hence to get more appropriate value the minimum number of noise free pixel is considered as eight. Whereas the minimum filter size is defined as 5×5 and maximum filter size is defined as 21× 21.

In order to improve the performance of SAMF some variations depending on the shape and size of filtering window with different median filtering techniques was incorporated. This results into new kind of filters namely Circular SAMF (CSAMF), Weighted SAMF (WSAMF) and Weighted CSAMF. Here circular shape and weighted coefficient is fused with SAMF.

IX. PERFORMANCE COMPARISON

It is observed that Simple adaptive Median filter performs well in terms of both Pick Signal to Noise ratio (PSNR) and Mean square Error (MSE).

The performance comparison of MF, AMF, SAMF filters are shown in Table 1. Here a filter of size 21×21 is used to filter the Lena image at different noise density level.

Noise Density	PSNR (DB)		
	MF	AMF	SAMF
20%	29.16276	34.38793	39.44658
50%	15.01889	20.9874	32.76267
80%	7.739613	14.15797	24.45557

Table1. Comparison of PSNR value for MF, AMF, SAMF for Lena image[21]

As the noise density level in an image increases the PSNR value of SAMF is high as compared to other denoising algorithms. Whereas if CSAMF, WCSAMF, WSAMF are considered SAMF has less efficiency in terms of both PSNR and Mean square error (MSE). Circular filter implementation takes large time than that of square filter, which increases the time complexity of CSAMF and WCSAMF.

X. PROPOSED WORK

In Proposed system, an algorithm in the category of SAMF is used to denoise the image sequence or video.The results of denoising will be in the form of image quality factors.Themultipleviews formation of same noisyvideo takes place and will undergodenoising process separately using selected filter. The fusion of all the views will generate the actual output video with noise suppression.Comparison and analysis of the results generated with both approaches will be performed.

XI. CONCLUSION

In this paper, an introduction regarding types of noise as well as classification of denoising algorithms is discussed. Some basic non-linear, spatial domain denoising algorithms are described with improvement over each other. A conventional median filter with little changes into it results into great rise in quality measures of resultant digital image.Adapting variable filter size and noise detection technique implemented in SAMF increases the PSNR value drastically for high density noise filtering. But in case of low noise density filtering the MF, AMF performs relatively good as compared with SAMF. Hence selection of denoising algorithm differs with conditions depending upon type of noise and noise density.

REFERENCES

[1] Vladimir Zlokolica, Aleksandra Pizurica, and Wilfried Philips, “Video denoising using multiple class averaging with Multiresolution”,University of Ghent, Sint-Pietersnieuwstraat 41,9000 Ghent, Belgium,VLBV2003,LNCS 2849,PP. 172-179,2003, *Springer*verlog berlin Heidelberg 2003.

[2] Bovik, Alan C.: Handbook of Image and Video Processing (Communications, Networking and Multimedia). Academic Press, Inc., Orlando, FL, USA, (2005).

[3] Rafael C. Gonzalez, Richard E. Woods, Book on “Digital Image Processing”, third edition, Pearson Education, pp.156-157,326,332-335,369©2008.

[4] Maria Petrou, and PanagiotaBosdogianni, ‘’Image Processing: The fundamental’’,John Wiley & Sons Ltd,2000.

[5] Sung-JeaKo, and YoogHoon Lee, ’’Center weighted median filters and their application to image enhancement’’, *IEEE Trans. Circuits and System*, vol. 38, no. 9, pp. 984-993, September 1991

[6] R. Yang, L. Yin, M. Gabbouj, J. Astola, and Y.Neuvo, “optimal weighted median filters under structural constraints”, *IEEE Trans. Signal Processing*, vol. 43, pp. 591-604, Mar. 1995.

[7] Arce G, Paredes J, “Recursive Weighted Median Filters Admitting Negative Weights and Their Optimization”, *IEEE Trans. on Signal Proc*., Vol. 48, 2000, pp 768-779

[8] WANG Chang-you, LI Lin-lin, YANG Fu-ping, GONG Hui, “A new kind of adaptive weighted median filter algorithm**”,***International Conference on Computer Application and System Modeling (ICCASM 2010),* volume 11-667,2010, 978-1-4244-7237-6/$26.00 C 2010 IEEE.

[9] T.-C. Lin, P.-T. Yu, “A new adaptive center weighted median filter for suppressing impulsivenoise in images”, Information Sciences 177 (2007) 1073–1087.

[10] T.C Chen, K.K. Ma and L.H. Chen, “Tri-state median filter for image denoising”, *IEEE Transactions on Image Processing*, vol. 8, No. 12, Dec. 1999, pp. 1834-1838.

[11] HadiSadoghiYazdi, FaranakHomayouni, “Impulse Noise Suppression Of Image Using Adaptive median Filter”, *International journal of signal processing, image processing and pattern Recognition*, vol. 3, No. 3, September 2010.

[12] Tamer Rabie**,** “Adaptive hybrid mean and median filtering of high-ISO long-exposure sensor noise for digital photography”,

Journal of Electronic Imaging, volume 13(2), 264–277 (April 2004).

[13] Mark DeNies, "survey of image denoising algorithm and noise estimation", DeNies software,September 2012

[14] R.C Hardie and K.E. Barner, "Rank conditioned rank selection filters for signal restoration", *IEEE Trans. Image Processing*, vol. 3, pp. 192-206, Mar. 1994.

[15] A. Ben Hamza, P. Luque, J. Martinez, and R. Roman, "Removing noise and preserving details with relaxed median filters", *J. Math. Image Vision*, volume 11, no. 2, pp. 161-177, October 1999.

[16] A.K. Jain, fundamentals of digital image processing. Prentice-Hall, 1989.

[17] David L. Donoho and lain M. Johnstone., "Ideal spatial adaption via wavelet shrinkage", *Biometrika*, vol. 81, September 1994.

[18] MukeshMotwani, MukeshGadiya, RakhiMotwani, and Frederick C. Harris, Jr., "Survey of Image Denoising Techniques," in *Proceedings of GSPx 2004,* September 27-30, 2004, Santa Clara Convention Center, Santa Clara, CA.

[19] A. Hyvarinen, E Oja, P.Hoyer, and j. Hurri, "Image feature extraction by sparse coding and Independent component analysis", *In Proc. International conference on pattern recognition (ICPR),* 1998.

[20] Wei Ping*, Li Junli†, Lu Dongming*, Chen Gang „A Fast and reliable switching median filter for highly corrupted images by impulse noise‟ *IEEE Transactions* 2007

[21] KavitaTewari, Manorama V. Tiwari, "Efficient Removal of Impulse Noise in Digital Images", *International Journal of Scientific and Research Publications*, Volume 2, Issue 10, October 2012 1

[22] Haidi Ibrahim, Nicholas SiaPik Kong, and Theam Foo Ng, "Simple adaptive median filter for the removal of impulse noise from highly corrupted images", *IEEE Trans. Consumer Electronics*, vol. 54, no. 4, pp. 1920-1927, November 2008.