Comparative Analysis of Different Algorithm for Removal of High Density Salt and Pepper Noise

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Abstract. This paper proposes comparison of different types of non-linear filter like median-type noise detector and edge preserving method, new decision based algorithm (DBA), new algorithm with modified shear sorting method and modified decision based un-symmetric trimmed median(MDBUTM) Filters used for restoration of the image containing high density salt and pepper noise as high as 90%. The results of different algorithms are compared to get the best method to achieve better peak signal-to-noise ratio (PSNR), image enhancement factor (IEF) and less computation time. Different algorithms are studied on different window size to find better results in terms of the qualitative and quantitative measures of the image.

Keywords: Impulse noise, shear sort, decision-based filter, trimmed filter, nonlinear filter.

1. Introduction

Image processing is a processing of images using mathematical operations by using any form of signal processing for which the input is an image, such photograph or video frame, the output of image processing may be either an image or set of characteristics or parameters related to the image. It is useful for noise reduction like, salt and pepper noise which occurs due to faulty communication [1] [2]. Salt and pepper noise [3] is also referred as impulse noise. Impulse noise can be defined as acoustic noise. Noise of this kind is mainly caused due to malfunctioning pixels in camera sensors, faulty memory locations in hardware [4] or due to a bit error in transmission of signal. Oftenly, images are corrupted by impulse noise or salt and pepper noise (which is also a type of impulse noise). When an image is corrupted with noise then there is an appearance of white and black spots (pixels) on the image. For an image corrupted by salt and pepper noise, the noise pixels can take only the maximum and minimum values (0, 255) where 0's as pepper noise and 255's as salt noise in the dynamic range [5] [6]. The pixel is said to be noise pixel (noise candidate) if its value does not lie within the range of (0, 255) and if it is within the range then it is known as uncorrupted pixels. In order to remove the noise, filters like linear or non-linear filters are used, but in case of removal of impulse noise linear filters are not effective so non-linear filters are preferred for restoration of corrupted images. Several filters like adaptive median filter (AMF), standard median filter (SMF), decision based algorithm (DBA) and robust estimation algorithm (REA) are used in denoising an image. The filter is applied to the selected noise candidates not to the whole image. The filter or algorithm is effective if it gives high PSNR and better recovered image in case of high noise density.

In case of Median filter, it is good for denoising power [4] and computational efficiency [7]. However, when the noise level is over 50%, some details and edges are smeared by the filter [8]. AMF performs well at low noise density, it identifies the noise candidates [9] and then replace them with median value of the window or with its neighbourhood pixel, the noise pixel value and median value have lesser correlation between them, where as there is better correlation between noise pixel value and neighbourhood pixel value. MDBUTMF can also be used to denoise the video containing impulse noise.

In this paper, different algorithms are compared to find out the best and effective method for removal of noise without losing the local features of the image and to solve the blurring of image for large window size, poor noise removal for smaller window size. In order to improve the computational efficiency modified shear sorting algorithm is used.

2. Comparison of Different Algorithm

2.1 Median type noise detectors and detail preserving regularization algorithm

In this algorithm there is a removal of Salt and pepper noise by Median type Noise Detector and Detail Preserving Regularization. According to this algorithm if there is a use of DBA or Median-type filters, the identified noise pixels are replaced by median value or it's variant, while leaving all other pixels unchanged. These filters can also work at high noise level. But the main drawback of this is that there is a replacement of noisy pixel by media value without taking into account local features such as possible presence of edges, which gives unsatisfactory results.

In this paper a powerful Two-Stage scheme is used, in which there is an adaptive median filter in phase-1 and a specialized regularization method in phase-2. An adaptive median filter is used to identify the noise candidates from the window and replace noise pixel by median value while the uncorrupted pixel are left unchanged. Edge regularization method is used to preserve edges [6] of the image during denoising; it can also be used for images corrupted by Gaussian noise.

Method for Impulse noise cleaning:

Images corrupted by impulse noise are recovered by minimising a convex objective function.

$$F_Y : R^{M\times N} \rightarrow R$$

This scheme achieves a significant high PSNR and low MAE. It successfully suppress the noise with the details and the edges of the image are preserved very accurately, even at high noise density (<=90%). But the main drawback of this scheme is computational complexity i.e. its processing time is very high due to the use of large window size 39×39 in both phases to obtain the optimum output, also more complex circuitry is needed for implementation and determination of smoothing factor 'β'.

2.2 Fast and efficient DBA

In this paper, a new decision based algorithm is used for restoration of images that are highly corrupted by impulse noise. Unlike all other non-linear filters, this filter also removes only corrupted pixels by replacing them with the median value of the window or by its neighbourhood pixel [10], because at high noise level the median value may also be a noise pixel so neighbourhood pixel is used in place of median value. This provides a better correlation between corrupted and neighbourhood pixel, which gives better edge preservation and more edge details.

In this technique after detection of impulse noise sorting is done, the steps for which is given below [10]:

Step 1: A 2-D window 'S_{xy}'of size 3x3 is selected. $P(X,Y)$ the pixel to be processed.

Step 2: The pixel value inside the window are sorted, and $P_{min,}$ p_{max} and p_{med} are determined as follows

a) The rows of the window are arranged in ascending order.
b) The columns of the window are arranged in ascending order.
c) The right diagonal of the window is now arranged in ascending order.

where, first element of the window is the minimum value P_{min} , last element of the window is maximum value P_{max} and middle element of the window is median value P_{med} .

Case 1: Selected Window (Processing pixel is not noisy, the same value is retained)

$$\underset{\text{Row Sorting}}{\begin{pmatrix} 0 & 0 & 255 \\ 122 & 123 & 255 \\ 0 & 255 & 255 \end{pmatrix}} \Rightarrow \underset{\text{Column Sorting}}{\begin{pmatrix} 0 & 0 & 255 \\ 0 & 123 & 255 \\ 122 & 255 & 255 \end{pmatrix}} \Rightarrow \underset{\text{Median}}{\begin{pmatrix} 0 & 0 & 122 \\ 0 & 123 & \\ 255 & 255 & 255 \end{pmatrix}}$$

Case 2: Selected Window (Processing pixel is noisy, replaced by median value)

$$\begin{pmatrix} 122 & 123 & 255 \\ 0 & 255 & 255 \\ 0 & 122 & 255 \end{pmatrix} \Rightarrow \begin{pmatrix} 0 & 122 & 255 \\ 0 & 123 & 255 \\ 122 & 255 & 255 \end{pmatrix} \Rightarrow \begin{pmatrix} 0 & 122 & 122 \\ 0 & 123 & \\ 255 & 255 & 255 \end{pmatrix}$$

Row Sorting Column Sorting Median

Case 3: Selected Window (Processing pixel and median are noisy, is replaced by neighbourhood)

$$\begin{pmatrix} 0 & 0 & 255 \\ 123 & 255 & 255 \\ 255 & 255 & 255 \end{pmatrix} \Rightarrow \begin{pmatrix} 0 & 0 & 255 \\ 123 & 255 & 255 \\ 255 & 255 & 255 \end{pmatrix} \Rightarrow \begin{pmatrix} 0 & 0 & 255 \\ 123 & 255 & \\ 255 & 255 & 255 \end{pmatrix}$$

Row Sorting Column Sorting Median

Step 3:

Case 1) The P(X, Y) is an uncorrupted pixel if $P_{min} < P(X, Y) < P_{max}$, $P_{min} > 0$ and $P_{max} < 255$; the pixel being processed is left unchanged. Otherwise, P(X, Y) is a corrupted pixel.

Case 2) If P(X, Y) is a corrupted pixel, it is replaced by its median value if $P_{min} < P_{med} < P_{max}$ and $0 < P_{med} < 255$.

Case 3) if $P_{min} < P_{med} < P_{max}$ is not satisfied or $255 < P_{med} = 0$, then P_{med} is a noise pixel. In this case, P(X, Y) is replaced by the neighbourhood pixel value.

Step 4: Steps 1 to 3 are repeated until the processing is completed for the entire image.

It uses 3×3 window size having only neighbours of the corrupted pixel that have higher correlation which provides more edge details, leading to better edge preservation. The main purpose of this algorithm is to solve problem like blurring of images for large window size and poor noise removal for smaller window size, which are common in SMF's [10].

This algorithm has PSNR values and much smaller computation time, reduced by the factor of 150 to 200 as compared to two phase algorithm [5]. In this paper noise removal is up to 90% noise density and edges are preserved up to 80%. It requires simple physical realization structure [10].

2.3 New and efficient algorithm with modified shear sorting method

In this paper, a new algorithm is used to remove high density salt and pepper noise in images and videos, by using modified sheer sorting method on 3×3 window size. It has less computation time with better visual appearance and quantitative measure at higher noise density as high as 90% [11]. In DBA and AMF there is a replacement of noise pixel with its neighbourhood pixel which gives better correlation results, but sometimes there is a occurrence of streaking effect due to replacement of noise pixel with the neighbourhood pixel value [10] where as in case of decision based unsymmetrical trimmed median filter (DBUTM), the noise pixel are identified and processed. In this the replacement of noise pixel with median value takes place after trimming impulse values. In order to improve computational efficiency modified shear sorting algorithm is used [11] along with DBUTM.

The algorithm for DBUTM is as follows [11]:

Step 1: A 2-D 'S_{xy}' of size 3×3 is selected.

Step 2: The pixel value in the window is sorted in ascending order, and stored in 1-D array.

Step 3: If the pixel value in the array is either '0' or '255', the corresponding pixel value is trimmed and median of remaining values is calculated.

Step 4: The pixel being processed is replaced by the median value calculated.

Now move the window by one step, and repeat from step 2 to step 4. The above steps are repeated, until the processing is completed for entire image.

For the implementation of noise video sequence:

Following are the steps in order to denoise the video containing impulse noise.

Step 1: The video containing impulse noise is first converted into frames and frames into images.
Step 2: Afterwards DBUTM is applied on the noise images.
Step 3: After the entire process. The denoised images are converted into frames and then frames into video.

2.4 MDBUTMF algorithm

In this algorithm a modified DBUTMF is used for denoising the image that is corrupted with high density salt and pepper noise. To avoid the streaking effect [12], DBUTMF is used. At high noise density, the trimmed value cannot be obtained if the selected window contains all 0's or 255's or both [13]. So DBUTMF does not give better result at high noise density 80% to 90%. To overcome this drawback modified decision based un-symmetric trimmed median filter (MDBUTMF) is applied to achieve better peak signal-to-noise ratio and image enhancement factor values. Un-symmetric trimmed median filter (UTMF) is used instead of alpha trimmed mean filtering (ATMF) because in case of ATMF, even uncorrupted pixels are also trimmed which leads to blurring and loss of details of image. In UTMF, the elements of window are arranged in ascending or descending order and noise pixels (0's and 255's) are removed from the image. Then the median of the remaining value is taken and noise candidate is replaced by this median value. The pixels which are not noisy or uncorrupted are left unchanged.
The steps of the MDBUTMF are elucidated as follows:
Step 1: Select 2-D window of size 3×3. Assume that P_{ij} is the pixel being processed.
Step 2: If $0 < P_{ij} < 255$ then P_{ij} is uncorrupted pixel and it is left unchanged.
Step 3: If $P_{ij} = 0$ or $P_{ij} = 255$ then P_{ij} is a corrupted pixel then there are two cases:
Case 1: If in the selected window all the elements are 0's and 255's then P_{ij} is replace with the mean of the elements of the window.
Case 2: If the selected window does not contain all the elements as 0 and 255 then P_{ij} is replace with the median value of the window.
Step 4: All the steps from (1-3) are repeated until the entire process is completed.
The MDBUTMF is also use to process the colour images that are corrupted by salt and pepper noise [11].

3. Performance Matrices

The performances of different techniques are studied with gray scale image Lena with different noise levels and the dynamic range of values [0, 255]. In the result of simulation, images are corrupted by impulse noise (salt and pepper noise) where "0" represents 'pepper' and "255" represents 'salt' noise with equal probability. The different noise levels are 70% and 90% and restoration performances are quantitatively measured by the peak signal-to-noise ratio (PSNR) and image enhancement factor (IEF) is defined in equation (1) and (3) respectively.

$$PSNR = 10\log_{10}\left(\frac{255^2}{MSE}\right) \tag{1}$$

$$MSE = \sum_{ij}\frac{\left(r_{ij} - x_{ij}\right)^2}{M \times N} \tag{2}$$

$$IEF = \frac{\left(\sum_{ij} n_{ij} - x_{ij}\right)^2}{\left(\sum_{ij} x_{ij} - r_{ij}\right)^2} \tag{3}$$

where r_{ij}, x_{ij} and n_{ij} denote the pixel values of the restored image, corrupted image and the original image respectively, whereas $M \times N$ is the size of the image.
The simulation results of table 1 show the comparison of CPU time in seconds and table 2 and 3 shows the comparison of PSNR and IEF values respectively.

Table 1. Comparison Table of CPU Time in Seconds for LENNA Image

Method	Noise density = 70%	Noise density = 90%
Median type noise detector (window 39×39) [5]	2009	6917
DBA (window 3×3) [10]	36.10	36.25

Table 2. Comparison Table of PSNR (dB) for LENNA Image

Method	Noise density = 70%	Noise density = 90%
Median type noise detector [5]	29.3	25.4
DBA [10]	28.62	23.94
MDBUTMF[13]	24.30	18.40

Table 3. Comparison Table of IEF Values for LENNA Image

Method	Noise density = 70%	Noise density = 90%
Median type noise detector [5]	146.0	45.13
DBA [10]	171.69	34.23

4. Conclusions

In this paper, the main motive is to find out best algorithm, in comparison with various filters to remove salt and pepper noise. From the simulation results, it is concluded that the MDBUTMF algorithm is the best among the rest of algorithms which gives better visual and quantitative results even at high noise density.

References

[1] W.K. Pratt. (1978). *Digital Image Processing*, New York: Wiley.
[2] I. Pitas and A. N. Venetsanopoulous. (1990). *Non-Linear Digital Filter Principles and Applications*. Boston: Kluwer Academic publisher.
[3] M. H. Hsieh, F. C.Chieng, M. C. Shie and S. J. Ruan, "Fast and efficient median filter for remo- ving 1-99% levels of salt and pepper noise in images," *Engineering Applications of Artifical Intelligence* 26, pp. 1333-1338, 2013.
[4] A. Bovik. (2000). *Handbook of Image and Video Processing*. New York: Academic.
[5] R. H. Chan, C.W. Ho, and M. Nikolova, 'Salt and pepper noise removal by median type noise detectors and detail preserving regularization," *IEEE Transactions on Image Processing*, vol. 14,no. 10, pp. 1479-1485, Oct. 2005.

[6] A. Kumar, N. Agarwal, J. Bhadviya, G. Mittal and G. Ramponi, "An Efficient New Edge Pres- erving Technique for Removal of Salt and Pepper Noise," in 8th International Symposium on Image and Signal Processing and Analysis, pp. 16-19, Sept. 2013.

[7] T. S. Huang, G.J. Yang, and G. Y. Tang, "Fast two-dimensional median filtering algorithm," *IEEE Transactions on Acoustics, Speech, Signal Processing*, vol. ASSP-1, no. 1, pp 13-18, 1979.

[8] T. A. Nodes and N. C. Gallagher, Jr., "The output distribution of median type filters," *IEEE Transactions on Communication*, vol. COM-32, no. 5, pp. 532-541, May 1984.

[9] M. Aldinucci, C. Spampinato, M. Drocco, M. Torquati and S. Palazzo, "A Parallel Edge Preserving Algorithm for Salt and Pepper Image Denoising," *Image Processing Theory, Tools and Applications*, 2012.

[10] K. S. Srinivasam and D. Ebenezer, "A new fast and efficient decision based algorithm for removal of high density impulse noise," *IEEE Signal Processing Letter,* vol. 14, no. 3, pp. 189-192, March 2007.

[11] K. Aishwarya, V. Jayaraj and D. Ebenezer, "A new and efficient algorithm for the removal of high density salt and pepper noise in images and videos," in *Second international Conference Computer Modelling and Simulation*, pp. 409-413, 2010.

[12] V. Jayaraj and D. Ebenezer, "A new switching-based median filtering scheme and algorithm for removal of high density salt and pepper noise in image," *EURASIP J. Advance Signal Processing,* June 2010.

[13] S. Esakkirajan, T. Veerakumar, Adabala N. Subremanyam and C.H. Prem Chand, "Removal of high density salt and pepper noise through modified decision based unsymmetric trimmed median filter," *IEEE Signal Processing Letter*, vol. 18, no. 5, pp. 287-290, May 2011.