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A Weighted Trimmed Mean Median Filter For Elimination In Digital Color Image

Ashish Nagle, Prof. Sumit Sharma, Dr Jitendra Agrawal
[1]M Tech Scholar, [2]Head of Department CSE, [3]Professor IT
[1,2] Deptt. of Computer Science Engineering, [3]Deptt. of Information Technology
[1,2] Vashnavi Institute of Technology (VIT), [3]School of Information Technology (SoIT), RGPV, Bhopal (M.P.)
ashishnagle100@gmail.com

Abstract*— In this proposed filter has proved that it is very efficient for impulse noise because practically noise is not uniform over the channel. We have used concept of weighted trimmed Mean Median filter for detection and removal of impulse noise. It produces very good PSNR (Peak Signal to Noise Ratio) [19], very small MSE (Mean Square Error), and good SSIM for highly noisy images, especially for more than 30% noise density. This algorithm is simple and requires low calculations than other filters like NAFSMF, MDBUTMF, NAFSMF, AWMF, DAMF, FDS, ARmF and IAWMF etc. The comprehensive small size of filtering window (3X3) gives advantage of preservation of fine details of image. Because of its less complexity of calculation, this filter will have great application in the field of image processing. The result images clearly indicate that the quality of de-noised image is better in visual form at that much high noise density. The proposed method improved the quality of de-noised image especially for higher impulse noise level.

***Keywords*— Image denoising, median filter, noise detection, noise removal, sequentially weighted median filter, 3σ principle.etc** *principle.etc.*

I. Introduction

An image is often corrupted by impulse noise in the process of acquisition and transmission; and there are two types of impulse noise: fixed-valued impulse noise and random valued impulse noise. Fixed-valued impulse noise is also called salt and pepper noise, one most common noise in images; it severely impacts the image processing and analysis, such as image recognition, segmentation, and so on. Therefore, effective removal of impulse noise is highly needed. For removal of fixed-valued impulse noise, the mean filter and median filter were originally proposed. However, mean filter was found unable to preserve the structure and edge information of image, while median filter is preferred because of its simple processing and good performance. But thereafter, the traditional median filter was found unable to obtain a thorough noise removal and structure information preservation simultaneously, especially

for high density noise, because it processes all pixels regardless of whether they are noisy or not, destroying the noise free pixels. To address this problem, some researchers initially proposed prepossessing. The associate editor coordinating the review of this manuscript and approving it for publication was Halil Ersin Soken. switching median filters that integrate the noise removal processing with a noise detector so as to make the removal processing imposed only on the detected noisy pixels so that the performance of median filter was improved considerably. And in the wake of development of image processing, analysis, and application, the better denoising performance of filters is highly demanded; thus, various improved filters integrated with various strategies were proposed. However, the existing filters inevitably have inherent shortcomings, and are not necessarily effective, especially for high density noise: they either overly smooth the image, or are unable to restore effectively the structural and edge information, so that they still could not satisfy the high requirements of image analysis. Adaptive Sequentially Weighted Median Filter for Image Highly Corrupted by Impulse Noise the noisy pixels from the noise free ones having the same intensity.A noise removal method employing sequentially weighted median of neighborhood of adaptive size; the weighted operator employed is derived in reference to the spatial distances from central noisy pixel, in which the weighting coefficients

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are sequentially inversely proportional to the spatial distances, distinguishing accurately the various contributions and impacts of neighbor pixels on the central noisy pixel according to the distances. The rest of this paper is organized by several parts as follows. Section II states the related works, followed by the proposed method detailed in section III; the experiments and result analyses are conducted in section IV; and section V concludes this paper extensively.

II. Literature Review

Alekya, Kanuri, et.al (2021) **-**In this research work, author present that in a non-straight channel, open assets channel is a specific situation that is utilized to lessen the Gaussian clamor in our paper and it performs well to diminish it. The significant favourable position of non-nearby methods channel is to save the cut off points and specifics of an exceptional picture. In this paper, consolidated both open methods channel and shared channel to suggest an improved channel for shading picture de-noising. Novel impact importance is processed by expansion consistency in arrangement into the weight to assess the equal of the fix. At the last phase of this paper bargains that the proposed strategy for NLM and BILF is a reasonable technique to diminish the Gaussian sound and blend of sound [01]. ***Patel, Punyaban, et.al (2021)*** **-**In this research work, author present denoising of digital images is one of the important pre-processing stages in image processing. In this paper, a new efficient back-propagation neural network-based impulse noise suppression technique is presented. The proposed technique works in two stages, i.e., impulse noise detection and noise filtering. In noise-detection stage, a feed-forward neural network is trained by back-propagation training algorithm to classify the noisy and non-noisy pixels in the test image. The input patterns for training are selected carefully to make the detector more robust for impulse detection. An adaptive median filtering is employed in the second stage for restoring the value of the noisy pixels identified in the first stage keeping the non-noisy ones unaltered. The restoration ability of the proposed method is evaluated using different standard images at different noise levels. It has been observed after several experiments on standard images that the performances of the proposed techniques are superior in terms of both visual quality and quantitative measurement [02].***Dabass, Jyoti, et.al (2021)*** **-** In this research work, author present, mortality rate because of breast cancer diminishes to a large extent if the categorization of breast lesions as malignant or benign is done properly but this process is quite complicated owing to erroneous detection of noisy pixels as false positives. It can be reduced by proper enhancement of cancer indicating features present in breast cancer ultrasound images. Therefore, the technique proposed for denoising, edge correction, and enhancement is pivoted around two drastic issues. The first issue is related to the blurring of important details because of improper noise suppression, whereas the second issue is associated with poor contrast between background tissues and masses in ultrasound images of breast cancer. In this paper, we presented an ensemble hybrid filter that restores the noisy ultrasound breast cancer images, corrects the edges of restored ultrasound images without getting degraded with additional Gaussian noise which degrades the ultrasound images during edge correction and finally enhances its visual quality. It uses Weiner filtering to remove a small amount of noise, fuzzy derivatives, and smoothing for edge preservation and intensification membership function along with contrast limited adaptive histogram equalization for enhancement. Experimental results are obtained to demonstrate the feasibility of the proposed approach. These results are also compared to traditional Weiner filter by numerical measures and visual inspection [03].

Ishikawa, Akari, et.al (2020) **-** In this research work, author present, with the recent extension of camera applications, image filtering is essential in image processing. Weighted median filtering is one of the image denoising method. The weighted median filter can be more useful for removing noise and blurring correction; however, its computational cost is high. Halide is a domain-specific language for image processing. By using Halide, we can easily optimize the code of image processing. In this study, we present weighted median filter with Halide code. Experimental results show that we can easily write the weighted median filter code [04].

Christo, Mary, et.al (2020) - In this research work, author present, A decision based asymmetrically trimmed Winsorized median for the removal of salt and pepper noise in images and videos is proposed. The proposed filter initially classifies the pixels as noisy and non noisy and later replaces the noisy pixels with asymmetrically trimmed modified winsorized median leaving the non noisy pixels unaltered. Exhaustive experiments were conducted on standard image database and the performance of the proposed filter was evaluated in terms of both quantitative and qualitatively with existing algorithm. It was found that the proposed algorithm was found to exhibit excellent noise suppression capabilities by preserving the fine information of the image even at higher noise densities. The performance of the proposed filter was found good even for videos. [05].

Biswas, Mantosh(2020) **-** In this research work, author presented, Impulse noise generally occurs because of bit errors in progression of image acquisition and transmission. It is well known that median filtering method is an impulse noise removal method. Lots of modified median filters have been proposed in the last decades to improve the methods for noise suppression and detail preservation, which have their own deficiencies while identifying and restoring noise pixels. In this article, after deeply analyzing the reasons, such as decreased noise detection and noise removal accuracy that forms the basis of the deficiencies, this article proposes a modified weighted median filter method for color images corrupted by salt-and-pepper noise. In this method, a pixel is classified into either “noise free pixel” or “noise pixel” by checking the center pixel in the current filtering window with the extreme values (0 or 255) for an 8-bit image using noise detection step. Directional differences and the number of “good” pixels in the current filtering window modify the detected noise pixels. Simulation effects on considered test images reveal the proposed method to be improved over state-of-the-art de-noising methods in terms of PSNR and SSIM with pictorial comparative analysis [06].

***Thanh, Dang et. al. (2019)* -** In this research work, author presented, an Iterative Mean Filter (IMF) to eliminate the salt-and-pepper noise. IMF uses the mean of gray values of noise-free pixels in a fixed-size window. Unlike other nonlinear filters, IMF does not enlarge the window size. A large size reduces the accuracy of noise removal. Therefore, IMF only uses a window with a size of 3×3 . This feature is helpful for IMF to be able to more precisely evaluate a new gray value for the center pixel. To process high-density noise effectively, we propose an iterative procedure for IMF. In the experiments, we operationalize Peak Signal-to-Noise Ratio (PSNR), Visual Information Fidelity, Image Enhancement Factor, Structural Similarity (SSIM), and Multiscale Structure Similarity to assess image quality. Furthermore, we compare denoising results of IMF with ones of the other state-of-the-art methods. A comprehensive comparison of execution time is also provided[07].

***George, Ginu et. al. (2018)* -** In this research work, author presented, The elimination of noise from images becomes a trending field in image processing. Images may got corrupted by random change in pixel intensity, illumination, or due to poor contrast and can't be used directly. Therefore, it is necessary to get rid of impulse noise presented in an image. In order to remove such impulse noise, Median based filters are commonly used. However, we use various types of median filters such as recursive median filter, iterative median filter, directional median filter, weighted median filter, adaptive median filter progressive switching median filter and threshold median filter. This paper will survey various median filtering techniques for excluding noisy pixel from a digital image [08].

Shi, Zhenghao et. al. (2018) - In this research work, author presented, a weighted median guided filtering method for rain removal with a single image. It consists of two filtering operations. Firstly, a weighted median filter is convoluted with an input rainy image to obtain a coarse rain-free image; then, guided filter is employed to obtain a refined rain-free image, where the coarse rain-free image is used as a guided image and convoluted with the input rainy image via guided filter. Experimental results show that the proposed method generated comparable results to the state-of-the-art algorithms with low computation cost [09].

***Khan, Sajid et. al. (2017)* -** In this research work, author presented, A new impulsive noise removal filter, adaptive dynamically weighted median filter (ADWMF), is proposed. A popular method for removing impulsive noise is a median filter whereas the weighted median filter and center weighted median filter were also investigated. ADWMF is based on weighted median filter. In ADWMF, instead of fixed weights, weightages of the filter are dynamically assigned with the results of noise detection. A simple and efficient noise detection method is also used to detect noise candidates and dynamically assign zero or small weights to the noise candidates in the window. This paper proposes an adaptive method which increases the window size according to the amounts of impulsive noise. Simulation results show that the AMWMF works better for both images with low and high density of impulsive noise than existing methods work [10].

III PROPOSED METHOD

At present there are many de-noising techniques available for impulse noise elimination for grayscale images and color scale images. In this research article, introduce a novel method for color impulse removal by modifying weighted mean filter **(**WMF) and selective weighted median filtering (WMF)There are several de-noising techniques are projected, many of them are application dependent. within the field of image process 2 main vital stages are 1st is detection stage and also the second is noise removal or improvement stage. The proposed method provides an optimum result in 3x3 window size and also gives a better image details meaning loss of the image information is low and better image quality at higher level of noise. In the projected methodology, simulate with the assistance of MATLAB, during this whole phenomena 1st we take a color image, then apply a hard and fast valued impulse noise (FVIN) is added to the targeted image, now have we got a colored noise image that is courted by color impulse noise.

A. First Step

When start the process on image processing first apply pee-processing task in color noisy images. First read this color noisy image then apply re-sizing of color image. After that divide a color noisy image into a three parts red (R), green (G) and blue (B) we all know very well that is RGB format. That is shown in below figure 1.

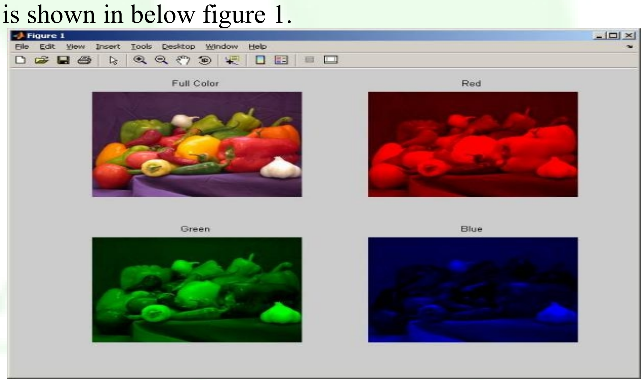

Fig. 1 Color image RGB form

Start →
Read (color image);
Resize (512X512)
Divide (R, G, B)
I(R) = (:, :, 1) // Red
I(G) = (:, :, 2) // Green
I(B) = (:, :, 3) // Blue

B. Second Step

Now color noisy image has three different 2D matrices that R, G and B. Now apply our detection stage at all three windows. Now we check the pixel region in all three frames.

// Impulse Noise Detection Stage
if
X (i,j) = 0<P(ij)<255 // Red frame
Y (i,j) = 0<P(ij)<255 // Green frame
Z (i,j) = 0<P(ij)<255 // blue frame
Noise free Pixels

else
Y_{ij} = Noise Pixel (Next Step) // combination of 0 and 255
End
// Detection complete

In the second phase, localized non-beacon nodes are also used for nodes localization with original beacon nodes. In the last phase, a mobile beacon node follow zigzag path and broadcast its position for node localization. The

C. Third Step

In the third step select any one frame in all three red (R), green (G) and blue (B) and take the smallest size of filtering window that is 3X3.There are nine elements in filtering window. Now we exclude central pixel for 3X3 for remaining pixel. Now detect the pixel whether the pixel is noise or noise free. Now three conditions arise i.e.

$X(i,j) \neq 0<P(i,j)<255$ // All Pixels are zero and 255
$Y(i,j) \neq 0<P(i,j)<255$// All Pixels are zero and 255
$Z(i,j) \neq 0<P(i,j)<255$// All Pixels are zero and 255

Table 1. Filtering window of size 3x3

	Column 1	Column 2	Column 3
Row 1	A_1	A_2	A_3
Row 2	A_4	Central Pixel	A_6
Row 3	A_7	A_8	A_9

1) In case A - If the elements in a 3X3 window are zeros it means that A1 to A9 all elements are zero –

// Weighted Mean Condition
if

$$Y_{ij} = \begin{matrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{matrix}$$

Weighted Mean = $\sum_{A1}^{A9} [Y_{ij}]$ /9
A5 = replace (Weighted Mean)
else
Forward to Step 3
end

2) In case B - If the elements in a 3X3 windows are ones it means that A1 to A9 all elements are ones -
// trimmed Median filter
if

$$Y_{ij} = \begin{matrix} 255 & 255 & 255 \\ 255 & 255 & 255 \\ 255 & 255 & 255 \end{matrix}$$

Trimmed Median = $\sum_{A1}^{A9}$ $[Y_{ij}]$
=
[255,255,255,255,**255**,255,255,255,255]
A5 = replace (Trimmed Median vale 5th element of array)

else

Forward to Step 3
End;

D. Fourth Step

Check the pixel values if in a small 3X3 window pixels are combination of zero's (0's) and ones (255's), it means that window contain both 0 and 255 elements. Then take a median of the remaining pixels expect central pixel or target pixel (A_5) and finally calculate the median of all W_1 to W_9 pixels and set in a place of targeted pixels (A_5).

$$\begin{matrix} 0 & 255 & 0 \\ 255 & 0 & 255 \\ 255 & 255 & 0 \end{matrix} \quad \{\text{Now take a } [A_5]\} \quad \begin{matrix} 0 & 255 & 0 \\ 255 & A5 & 255 \\ 255 & 255 & 0 \end{matrix}$$

Now calculate the weight of all elements
Weight of 255 [W (255)] = 2.5
Weight of Zero [W (0)] = 0
Apply this weight to the all 3X3 elements

$$\text{Weighted Median} = \begin{matrix} 0/0 & 255/2.5 & 0/0 \\ 255/2.5 & A5 & 255/2.5 \\ 255/2.5 & 255/2.5 & 0/0 \end{matrix}$$

Weighted Median =[0+102 + 0+102+102+102+102+0] /8
= 102
Weighted Median = replace to a central pixel A5 by 102.

E. Final Step

Now all the noisy pixels have been removed and the noise free pixels are restored in the respective color window. In the last step, the three basic color windows are combined together to get the noise free color image. If the filtering window that is 3X3.There are nine elements in filtering window The image obtained in the previous step is again de-noised by calculating the median value again, the targeted pixel is replaced by this median value. These phenomena are applying for all 3X3 windows for all (512X512) images.

IV. Simulation and Result

PSNR is typically expressed in terms of the logarithmic decibel (db) scale. This method is mainly used for high density noise because most of the algorithms produce good results at low noise density but very poor results at high noise density.

A. PSNR

The PSNR is expressed in shown in below eq.:The PSNR is most commonly used as a measure of quality of reconstruction of loss compression of resultant image.In the present work focus on color image. Color image contain red , green and blue frames (R,G,B).

Table 2 Result analysis of Mandril Image on various parameters

ND (%)	PSNR	SSIM	IEF	MSE	RMSE	Time
10	32.10	0.96	48.24	40.078	6.330	8.79
30	27.67	0.90	46.93	111.08	10.53	14.13
50	25.56	0.84	44.06	180.69	13.44	18.32
70	24.18	0.78	41.31	248.44	15.76	22.22
90	23.22	0.73	39.08	309.84	17.60	25.14

$$\text{PSNR(Color image)}= R\{10\log_{10}\frac{(255)^2}{(MSE)}\} + G\{10\log_{10}\frac{(255)^2}{(MSE)}\}+B\{10\log_{10}\frac{(255)^2}{(MSE)}\} \quad 1$$

B. MSE

MSE is the arycnam of mean square error (MSE). In this proposed worked on color image enchantment. Therefor calculate the three mean square values, mean square error at red, mean square error at green and mean square error at blue. At the end take a summation of red , green and blue and calculate final value of mean sqare error (MSE),

Where MSE is:

$$MSE(R) = \frac{\sum_{i=1}^{m}\sum_{j=1}^{255}\{Y(i,j) - \widehat{Y}(i,j)\}^2}{m \times n} \quad 2$$

$$MSE(G) = \frac{\sum_{i=1}^{m}\sum_{j=1}^{255}\{Y(i,j) - \widehat{Y}(i,j)\}^2}{m \times n}$$

$$MSE(B) = \frac{\sum_{i=1}^{m}\sum_{j=1}^{255}\{Y(i,j) - \widehat{Y}(i,j)\}^2}{m \times n}$$

Decimal Where MSE acronym of Mean Square Error stands for image enhancement factor, $m \times n$ is the size of image, Y shows the original image, $\widehat{Y}$ shows the de-noised image.

C. Root Mean Sqaure Error (RMSE)–

Mean sqaure error value at higher noise density contain higher values after point value. For compress this value use root mean sqaure error value (RMSE). RMSE is under root of MSE.

$$RMSE = \sqrt{\sum_{i=1}^{m}\sum_{j=1}^{255}\{MSE(r) + MSE(g) + MSE(b)\}}$$

In the below table 3 shows the result comparison of proposed filter with different previous filters which in shown in below table 3. For the result Comparison use peak signal to noise ratio at four different image – 'Lena', The result compare at four different noise density level which 20%, 40%, 60% ,and 80%. There are eight different previous methods are use for result comparison.

Mandrill Image Result

After the discussion of above two standard images barbera and pepper. Now analysis the result of Mandrill image which is simulated on matlab. The outcome of proposed filter is shown in below figure 2.

In the below table 3 shows different parameters value of the proposed algorithm. There are six different parameters represent at different noise density level between 10% to 90% noise density level.

Table. 3 Result Analysis Of Different Method On Various Noise Density

Method	20%	40%	60%	80%	Average
NAFSMF	34.14	30.56	27.9	24.83	29.34
MDBUTMF	36.57	31.45	25.77	17.82	27.9
NAFSMF	34.14	30.56	27.9	24.83	29.34
AWMF	36.53	34.26	31.36	27.68	32.46
DAMF	37.24	32.82	29.71	26.41	31.55
FDS	35.32	30.37	31.78	27.79	33.62
ARmF	39.51	35.39	31.78	27.79	33.62
IAWMF	39.52	35.42	31.98	28.27	33.80
Proposed	39.34	36.22	34.134	32.6007	35.572

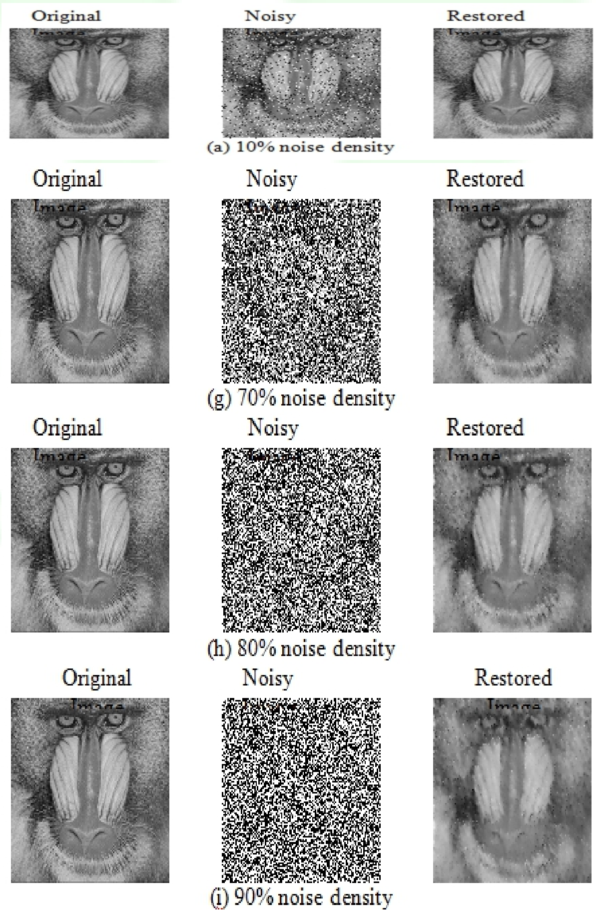

Fig. 2 Mandrill result at different noise density

In the figure 3 shows the graphical representation of peak signal to noise ratio at different noise density with methods. Shows Graphical comparison based on PSNR in between proposed method with different previous methods. In the graphical presentation clearly show that proposed method shows better PSNR vales as 40%, 60% ,80% as well as average value of all calculated results**.**

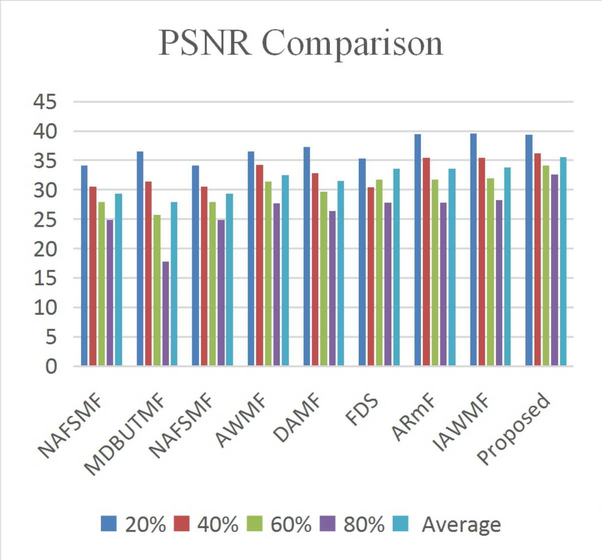

Fig. 3 Shows Graphical comparison based on PSNR in between proposed method with different previous methods

V. CONCLUSION

In this paper discussed the different methods for image noise removal. In the survey paper, discuss different impulse noise detection method. In this paper, we have discuss a different methods for impulse noise detection an removal. In this review we have see that there are different methods for image de-noising but also want to enhance the quality of images. In the case of digital image processing removal of impulse noise is important but also focus on image enhancements like edge preservation and other quality of images. Further we will proposed a new method for a removal of impulse noise as well as enhance the quality of images also.

REFERENCES

[1]. Alekya, Kanuri, Konala Vijayalakshmi, Nainavarapu Radha, and Durgesh Nandan. "Colour Image De-noising Analysis Based on Improved Non-local Mean Filter." In *ICCCE 2020*, pp. 1169-1178. Springer, Singapore, 2021.

[2]. Implementation Patel, Punyaban, and Bibekananda Jena. "Neural Network-Based Random-Valued Impulsive Noise Suppression Scheme." In *Intelligent System Design*, pp. 759-769. Springer, Singapore, 2021.

[3]. Dabass, Jyoti, and Manju Dabass. "Denoising, Edge Correction, and Enhancement of Breast Cancer Ultrasound Images." In *Advances in Communication and Computational Technology*, pp. 1153-1172. Springer, Singapore, 2021

[4]. Ishikawa, Akari, Hiroshi Tajima, and Norishige Fukushima. "Halide implementation of weighted median filter." In *International Workshop on Advanced Imaging Technology (IWAIT) 2020*, vol. 11515, p. 115152W. International Society for Optics and Photonics, 2020

[5]. Christo, Mary Subaja, K. Vasanth, and R. Varatharajan. "A decision based asymmetrically trimmed modified winsorized median filter for the removal of salt and pepper noise in images and videos."*Multimedia Tools and Applications* 79, no. 1 (2020): 415-432.

[6]. Biswas, Mantosh. "Impulse Noise Detection and Removal Method Based on Modified Weighted Median."*International Journal of Software Innovation (IJSI)* 8, no. 2 (2020): 38-53

[7]. Thanh, Dang Ngoc Hoang, and Serdar Engínoğlu. "An iterative mean filter for image denoising."*IEEE Access* 7 (2019): 167847-167859

[8]. George, Ginu, Rinoy Mathew Oommen, Shani Shelly, Stephie Sara Philipose, and Ann Mary Varghese. "A survey on various median filtering techniques for removal of impulse noise from digital image." In *2018 Conference on Emerging Devices and Smart Systems (ICEDSS)*, pp. 235-238. IEEE, 2018.

[9]. Shi, Zhenghao, Yaowei Li, Changqing Zhang, Minghua Zhao, Yaning Feng, and Bo Jiang. "Weighted median guided filtering method for single image rain removal."*EURASIP Journal on Image and Video Processing* 2018, no. 1 (2018): 1-8

[10]. Khan, Sajid, and Dong-Ho Lee. "An adaptive dynamically weighted median filter for impulse noise removal."*EURASIP Journal on Advances in Signal Processing* 2017, no. 1 (2017): 67

[11]. Faragallah, Osama S., and Hani M. Ibrahem. "Adaptive switching weighted median filter framework for suppressing salt-and-pepper noise."*AEU-International Journal of Electronics and Communications* 70, no. 8 (2016): 1034-1040.

[12]. Kunsoth, Raghuram, and Mantosh Biswas. "Modified decision based median filter for impulse noise removal." In *2016 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET)*, pp. 1316-1319. IEEE, 2016.

[13]. Kalyoncu, Cem, Önsen Toygar, and Hasan Demirel. "Interpolation-based impulse noise removal." IET Image Processing 7, no. 8 (2013): 777-785. (IBINR)

[14]. Jafar, Iyad F., Rami A. AlNa'mneh, and Khalid A. Darabkh. "Efficient improvements on the BDND filtering algorithm for the removal of high-density impulse noise." IEEE Transactions on Image Processing 22, no. 3 (2013): 1223-1232. (IBDND)

[15]. Pattnaik, Ashutosh, Sharad Agarwal, and Subhasis Chand. "A new and efficient method for removal of high density salt and pepper noise through cascade decision based filtering algorithm." Procedia Technology 6 (2012): 108-117.

[16]. Zhou, Zhe. "Cognition and removal of impulse noise with uncertainty." IEEE transactions on image processing 21, no. 7 (2012): 3157-3167. (CMF)

[17]. Esakkirajan, S., T. Veerakumar, Adabala N. Subramanyam, and C. H. PremChand. "Removal of high density salt and pepper noise through modified decision based unsymmetric trimmed median filter." IEEE Signal processing letters 18, no. 5 (2011): 287-290. (MDBUTMF)
[18]. Toh, Kenny Kal Vin, and Nor Ashidi Mat Isa. "Noise adaptive fuzzy switching median filter for salt-and-pepper noise reduction." IEEE signal processing letters 17, no. 3 (2010): 281-284.
[19]. Toprak, Abdullah, Mehmet Siraç Özerdem, and İnan Güler. "Suppression of impulse noise in MR images using artificial intelligent based neuro-fuzzy adaptive median filter." Digital Signal Processing 18, no. 3 (2008): 391-405.
[20]. Han, Min, Yuhua Liu, Jianhui Xi, and Wei Guo. "Noise smoothing for nonlinear time series using wavelet soft threshold." IEEE signal processing letters 14, no. 1 (2007): 62-65.
[21]. Lee, Suk-Ho, and Moon Gi Kang. "Total variation-based image noise reduction with generalized fidelity function." IEEE Signal Processing Letters 14, no. 11 (2007): 832-835.
[22]. Aizenberg, Igor, Constantine Butakoff, and Dmitriy Paliy. "Impulsive noise removal using threshold Boolean filtering based on the impulse detecting functions." IEEE Signal Processing Letters 12, no. 1 (2005): 63-66.
[23]. Garnett, Roman, Timothy Huegerich, Charles Chui, and Wenjie He. "A universal noise removal algorithm with an impulse detector." IEEE Transactions on image processing 14, no. 11 (2005): 1747-1754.
[24]. M.A. Erle Lin, H-M., and Alan N. Will son. "Median filters with adaptive length." IEEE Transactions on Circuits and Systems 35, no. 6 (1988): 675-690.

