

# Enhanced AMF & ACWMF Impulse Noise Removal Technique for Quantitative Measures of Signal Restoration of Image Quality

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**Abstract:** Images are often corrupted by impulse noise due to noisy sensors or channel transmission errors. In removing impulse noise from the acquired images, various linear and nonlinear filtering methods have been employed by various researchers. These have the drawback of blurring fine details and destroying image edges during noise filtering. In order to overcome this limitation without compromising the useful information content of the digital image, an enhanced AMF and ACWMF impulse noise removal technique by the combination of Artificial Neural Network (ANN) and nonlinear filters. ANN with a back propagation training algorithm was employed at the first stage to detect the impulse noise from the acquired digital images. The detected impulse in the digital image was removed at the second stage of the filtering using Adaptive Centre Weight Median Filter (ACWMF) and Adaptive Median Filter (AMF). Mean-square error (MSE), root mean-square error (RMSE) and the peak signal to noise ratio (PSNR) were used for performance evaluation with respect to the percentage of the noise in the corrupted image, and the result showed improvement both in quantitative measures of signal restoration and judgment of image quality.

**Keywords:** Digital Image, Adaptive Centre Weight Median Filter (ACWMF), Adaptive Median Filter (AMF), Mean-Square Error (MSE), Root Mean-Square Error (RMSE), The Peak Signal to Noise Ratio (PSNR), Artificial Neural Network (ANN)

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## 1. Introduction

An image processing system consists of a source of image data, a processing element and a destination for the processed results. An image may be subjected to different noise [1-2]. The presence of noise is manifested by undesirable information which is not at all related to the image under study but in turn disturbs the information present in the image. Noise having Gaussian-like distribution is very often encountered in acquired image. Generally, Gaussian noise is added to every part of the image and it affects each pixel in the image from its original value usually by a small amount based on noise standard deviation. Gaussian noise can easily be removed by locally averaging the pixels inside the window and replacing the processing pixel with this average value [3-5]. Another kind of noise that may be present during the image transmission is known as multiplicative noise also known as speckle noise.

Third type of noise is impulse noise; this can be Salt & Pepper Noise (SPN) or Random Valued Impulsive Noise (RVIN). This paper deals with impulse noise, impulse noise appears as sprinkle of light or dark spots in digital image [6], which may affect images at the time of acquisition due to noisy sensors or at the time of transmission due to channel errors or in storage media due to faulty hardware. and it can be eliminated by the use of advance filter which may be linear or nonlinear [7,8] in terms of impulse noise attenuation and edge/details preservation. A large number of methods have been proposed by researchers to remove noise from digital images. The median filter has been extensively studied due to its ability to suppress impulse noise computationally and efficiently. And not all these techniques detect the impulse noise before filtering is performed on them but also there are some who approaches that detection techniques are being used to before the image is being filtered. Abreu *et al* used a Rank-Ordered Mean filter which is an adaptive approach to solve the restoration problem in which filtering is conditioned

on the current state of the algorithm. The state variable is defined as the output of a classifier that acts on the differences between the current pixel value and the remaining ordered pixel values inside a window centered around the pixel of interest. This scheme is undoubtedly one of the robust and simple schemes but it fails in preserving the finer details of the image [9]. Chen and Wu used an Adaptive Center Weighted Median Filter this work is an improvement of previously described Center Weighted Median (CWM) filter. It works on the estimates based on the differences between the current pixel and the outputs of the CWM filters with varied center weights. These estimates decide the switching between the current pixel and median of the window. This is a good filter and is robust for a wide variety of images. But it is inefficient in recovering the exact values of the corrupted pixels. Butakoff and Aizenberg used Differential Ranked Impulse Detector This is another nonlinear technique which also works in two stages. It aims at filtering only corrupted pixels. Identification of such pixels is done by comparing signal samples within a narrow rank window by both rank and absolute value. The first estimate is based on the comparison between the rank of the pixel of interest and rank of the median. The second estimate is based on the brightness value which is analysed using the median. It is a good filter in low noise conditions but the performance slightly degrades in beyond 20% of noise. It also leaves noise blotch without correcting [10]. Jian-Feng Cai *et.al*, proposes a two-phase approach to restore images corrupted by blur and impulse noise. In the first phase, It identify the outlier candidates—the pixels that are likely to be corrupted by impulse noise. It considers that the remaining data pixels are essentially free of outliers. Then in the second phase, the image is deblurred and denoised simultaneously by a variational method by using the essentially outlier-free data. In general the two-phase method for salt-and-pepper noise performs better than for random-valued noise: it can handle salt-and-pepper noise as high as 90% but random-valued noise for about 55%. The main reason is that the former is easier to detect than the latter in the first phase. In fact, AMF is a very good detector for salt-and-pepper noise, and almost all the noise positions can be detected even when the noise ratio is very high. In addition, with salt and pepper noise, most of the noisy pixels are much more dissimilar to regular pixels, hence are easier to detect. However, there is no good detector for random valued noise when the noise ratio is high. The performance for random-valued noise can be improved if a better noise detector can be found in the first phase weighted median filter and the unidirectional multistage median filter in terms of mean absolute error and filtering speed [11]. R K Kulkarni *et.al*, proposes a simple yet effective algorithm for effectively denoising extremely corrupted image by impulse noise. The proposed method first classifies the pixels into two classes, which are “noise free pixel” and “noisy pixel” based on the intensity values. The corrupted pixels are replaced by “alpha trim- mean” value of uncorrupted pixels in the filtering window. The method adaptively changes the size of filtering window based on the number of “noise free pixels”. Because of this, the proposed method removes the noise much more effectively even at noise density as high as 80% and preserves the good image quality. Experimental results show that this method always produces good output, even when tested for high level of noise.

The details inside the image are preserved [12]. Ratna Babu *et al.* proposed a method Modified Median Filter to remove salt and pepper noise. In this proposed method, dummy rows and columns are added at each border to preserve edges. 3 X 3 neighborhood window is considered and central pixel of the neighborhood window is the processing pixel. A vector is used to maintain all neighborhood pixel intensity values except processing pixel. If all intensity values in the vector is 0 or 255 (Noisy), then processing pixel is replaced by mean value of all vector values. Here, instead of median value, mean value is calculated. If the intensity value of this vector is other than 0 or 255, then processing pixel value is replaced by the median of values in the vector. This proposed method performs well up to 70% of noise density [13]. Aalavandan *and* Sanboo proposed Adaptive Switching Median Filter (ASMF). This method is modified method of Switching Median Filter (SMF). Noise removal of this method is done by two stages. In the first stage, identifying noisy region. Here, a binary image is created using thresholding values where 0's in the binary image defines noise free pixel and is defines noisy pixels. In the second stage, using Adaptive Switching Median Filter, removal of noise. According to performance metrics, this proposed method gives best performance while preserving significant and edge details. This proposed method is capable of removing impulse noise [14]. Abdul Majid *et.al* proposes a novel impulse noise removal scheme that emphasizes on few noise free pixels and small neighborhood. The proposed scheme searches noise-free pixels within a small neighborhood. This scheme has provided better performance as compared to existing approaches. Moreover, this scheme is capable to restore the corrupted images while preserving edges and fine details. Experimental results show that the proposed scheme is capable of removing impulse noise effectively while preserving the fine image details. Especially, this approach has shown effectiveness against high impulse noise density [15]. Zayed M. Ramadan proposes a two-stage adaptive method for restoration of images corrupted with impulse noise. In the first stage, the pixels which are most likely contaminated by noise are detected based on their intensity values. In the second stage, an efficient average filtering algorithm is used to remove those noisy pixels from the image [16]. Only pixels which are determined to be noisy in the first stage are processed in the second stage. The remaining pixels of the first stage are not processed further and are just copied to their corresponding locations in the restored image. The experimental results for the proposed method demonstrate that it is faster and simpler than even median filtering, and it is very efficient for images corrupted with a wide range of impulse noise densities varying from 10% to 90%. Because of its simplicity, high speed, and low computational complexity, the proposed method can be used in real time digital image applications.

## 2. Methodology

The impulse noise filtering method in this work is a combination of Adaptive Center Weight Median Filter (ACWMF), Adaptive Median Filters (AMF) and Artificial Neural Network (ANN). The developed image filtering system is made up of two major stages, which include:

- i. Impulse noise detection using Artificial Neural Network (ANN)
- ii. Impulse noise removal using Non Linear Filters (AWCMF + AMF)

Comparative evaluations are made between the two-stage filtering method and each of ACWMF and AMF. Graphical user interface (GUI) was developed to evaluate the image filtering system in MATLAB software environment.

Digital image was acquired using Sony alpha A5100 camera, the image of various locations around Ladoko Akintola University of Technology, Ogbomoso, and Oyo state and Ondo state University of Science and Technology Okitipupa Ondo State. After capturing of the image, impulse noise was added to the image and detection of the impulse noise using ANN, the noise is filtered using non-linear filters.

### 2.1. Artificial Neural Network (ANN) for Noise Detection

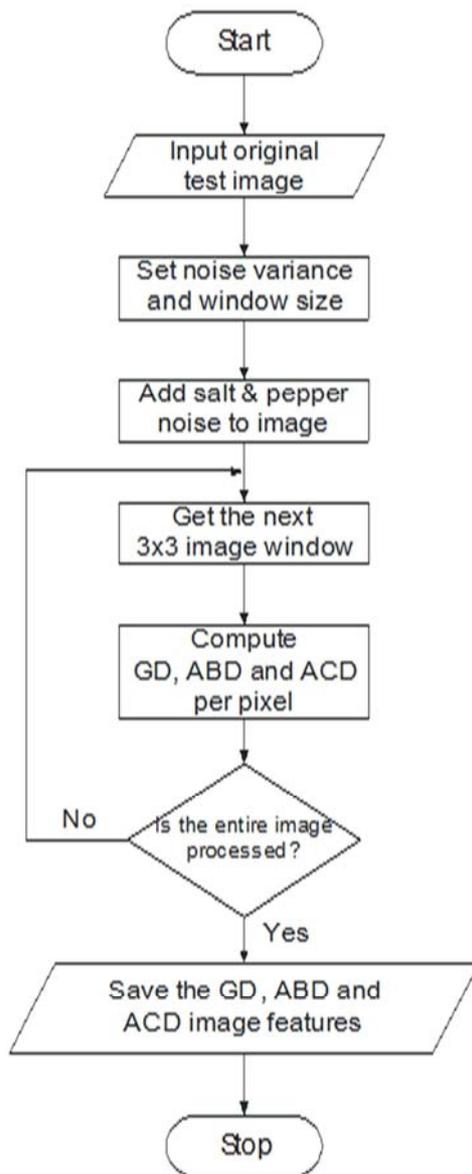


Figure 1. Feature extraction for the ANN training.

ANN is a training algorithm suitable for pattern classification. The pattern of noise pixels and clean pixels are used to train an ANN object for noise detection in any given window of image pixels. The pixels' features used to train the neural network are obtained from three methods namely Gray-level difference (GD), Average Background Difference (ABD) and Accumulation Complexity Difference (ACD). The input to the ANN is  $N \times 3$  matrix, where N is the total number of pixels, both noisy and clean, used as training data. The 3 columns of the matrix represent the GD, ABD and ACD values of the selected pixels for training. Figure 1 shows the process of obtaining the GD, ABD and ACD features for the ANN training process. The ANN learns how the patterns of noise pixels differ from the clean pixels in terms of the GD, ABD and ACD values.

In order to train the ANN, a grey-scale image of size  $92 \times 92$  was corrupted by impulse noise of noise variance 0.25. The indexes of both the corrupted and clean where identified, and each index was assigned a value of 1 (noise) or -1 (clean). These assigned values were used as the targets for the ANN. This implies that whenever the trained ANN object is used to test an input pixel, if it outputs 1 it is a noise pixel but if it outputs -1 it is a clean pixel. Figure 2 shows the training of a neural network for the detection of noise pixels.

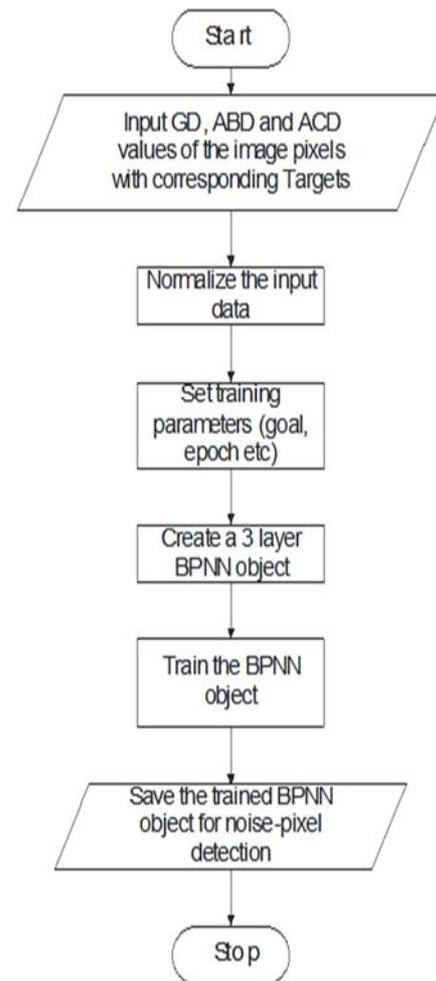


Figure 2. Training a neural network for detection of noise pixels in an image.

**2.2. Gray-Level Difference (GD)**

The GD represents the accumulated variations between the central pixels for identification and each surrounding local pixel. Assuming a  $3 \times 3$  window size of pixels  $I$ , the GD can be defined as:

$$GD = \sum_{i=1}^3 \sum_{\substack{j=1 \\ (i,j) \neq (2,2)}}^3 |I(2,2) - I(i,j)| \quad (1)$$

where  $I(2,2)$  is the reference pixel and  $I(i,j)$  is the surrounding local pixel. The corrupted pixels would yield very high GD values as compared with the uncorrupted pixels. However, the pixels in the edge regions would also yield very high GD values, and this prompts the use of ABD and ACD as additional features. Figure 3 shows the flow chart for the computation of a pixel's GD in a  $3 \times 3$  window.

**2.3. Average Background Difference (ABD)**

The ABD involves averaging the surrounding pixels as the background luminance (BL) of the sliding block to compare with the reference pixel. This represents the overall average variation with the reference pixel in the block and it is

defined as:

$$ABD = \left| I(2,2) - \frac{\sum_{i=1}^3 \sum_{\substack{j=1 \\ (i,j) \neq (2,2)}}^3 I(i,j)}{8} \right| \quad (2)$$

where  $I(2,2)$  is the reference pixel and  $I(i,j)$  is the surrounding local pixel. Figure 4 shows the flow chart for the computation of ABD in a  $3 \times 3$  window.

**2.4. Accumulation Complexity Difference (ACD)**

The ACD helps to differentiate between a noise pixel and a clean edge pixel. It involves finding the difference between each pixel in the  $3 \times 3$  window and its four neighbouring pixels. The accumulation in the edge area is relatively lower than that in the noise-pixel area. Figure 5 shows the flow chart for the computation of ACD in a  $3 \times 3$  window. The ACD is given as:

$$ACD = \sum_{i=1}^3 \sum_{j=1}^3 4 \times I(i,j) - I(i-1,j) - I(i+1,j) - I(i,j-1) - I(i,j+1) \quad (3)$$

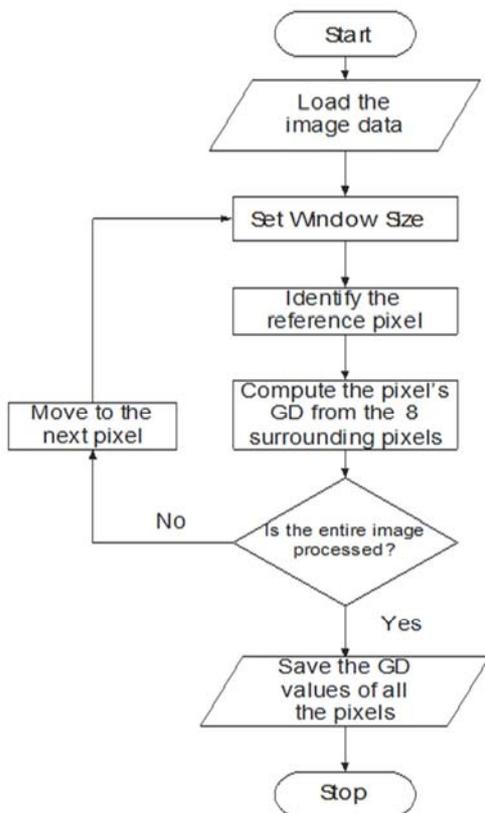


Figure 3. Computation of a pixel's GD.

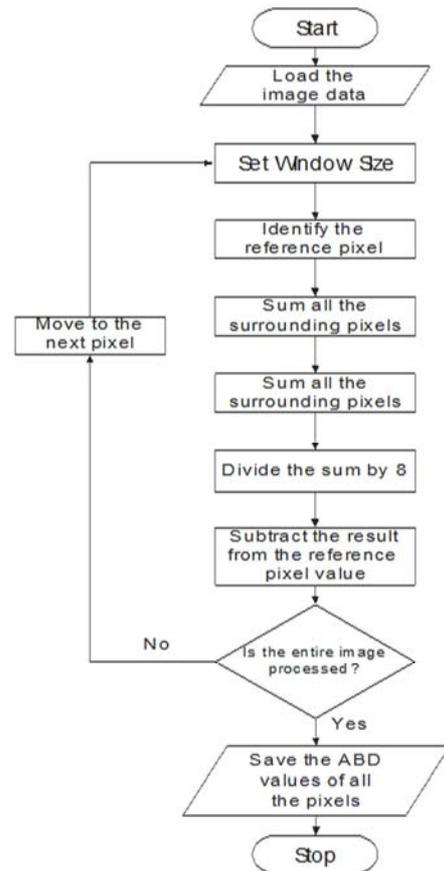


Figure 4. Computation of a pixel's ABD.

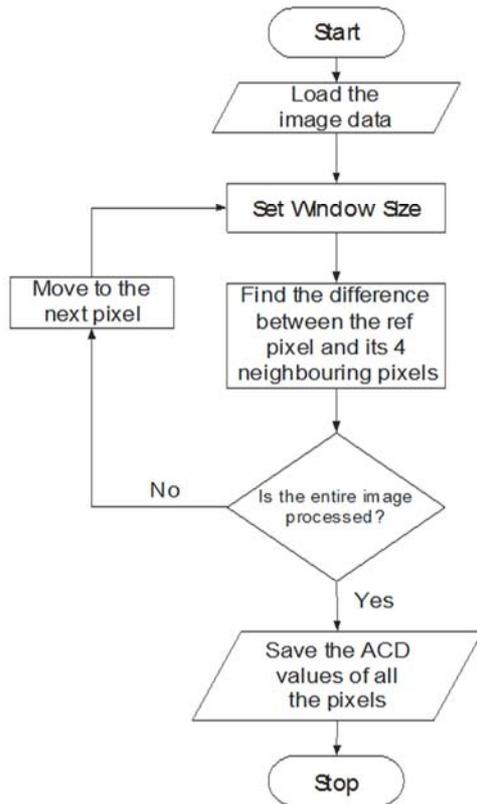


Figure 5. Computation of a pixel's ACD.

## 2.5. Impulse Noise Removal Technique

The concentration of impulse noise on an image is varied because impulse noise is a random noise. Therefore, there are regions of the image with high level of corruption, and there are also regions with low level of corruption. For an effective noise filtering process, a larger filter should be applied to regions with high level of corruption. In contrast, a smaller filter should be applied to regions with low level of corruption. These need call for an adaptive kind of filter that will perform the filtering process based on the level of impulse noise in the digital image. The first stage starts by detecting the presence of noise pixels in a window of pixels. If noise is detected the window is passed to the ACWMF for filtering but if no noise is detected, the window remains unchanged. This process is repeated until the entire image has been filtered. In the second stage, after the ACWMF process, if the noise density in the filtered image is greater than a threshold (30% in this study), another filtering is performed window by window using the AMF until the entire image has been processed. The third stage is the image quality enhancement stage whereby the several clean image pixels with dominant orientation are used as training patterns. Assuming a clean image portion is denoted by  $I$ , the noisy version of  $I$  has been filtered and the filtered result is denoted by  $I'$ . The input of the ANN is the compensated pixels  $I'$ , while the target output of the ANN are pixels obtained from the clean original image.

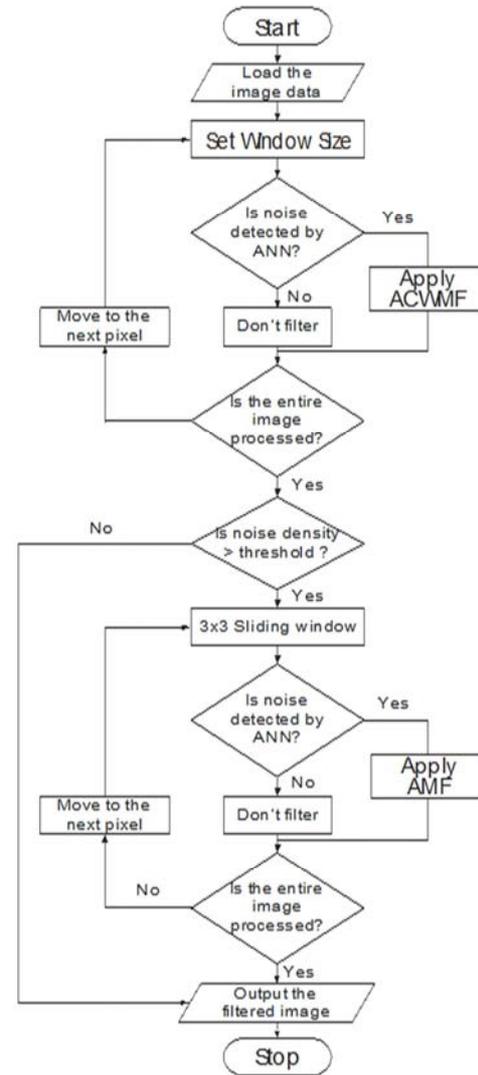


Figure 6. The filtering technique process.

## 2.6. Filtering Performance Metrics

In order to evaluate the performance of the proposed filtering method compared to the existing methods, the performance measures used include: Mean squared error (MSE), root mean squared error (RMSE) and Peak signal-to-noise ratio (PSNR).

### 2.6.1. Mean Squared Error (MSE)

The MSE is a measure of the difference between the original image and the filtered image. If the filtered image is almost a replica of the original image, the MSE value will be very low; however, if the filtered image is largely different from the original image, the MSE value will be very high. The MSE can be expressed as:

$$MSE = \frac{1}{MN} \sum_{j=1}^M \sum_{i=1}^N (O(i, j) - F(i, j))^2 \quad (4)$$

where  $O(i, j)$  is the pixel at row  $i$  and column  $j$  in the original image,  $F(i, j)$  is the pixel at row  $i$  and column  $j$  in the filtered image,  $N$  is the total number of rows and  $M$

is the total number of columns.

$$PSNR = 20 \log_{10} \left( \frac{255}{RMSE} \right) \quad (6)$$

**2.6.2. Root Mean Squared Error (RMSE)**

The RMSE is a function of the MSE and can be expressed as:

$$RMSE = \sqrt{\frac{1}{MN} \sum_{j=1}^M \sum_{i=1}^N (O(i, j) - F(i, j))^2} \quad (5)$$

**2.6.3. Peak Signal-to-Noise Ratio (PSNR)**

The PSNR is a measure of the effectiveness of a filter by revealing the quality of a filtered image. The higher the image quality the larger will be its PSNR value. The expression for measuring the PSNR is given as:

**3. Results and Discussion**

Filtering techniques is a combination of the ACWMF and AMF with enhancement, the first stage filtering is using ACWMF and AMF to filter the image without filtering. The AMF and ACWMF are applied to a noisy image to remove the impulse noise after impulse noise has been detected from the image. The percentage of noise is varied for each image and the resulted PSNR, MSE and RMSE are plotted, the results are discussed below.

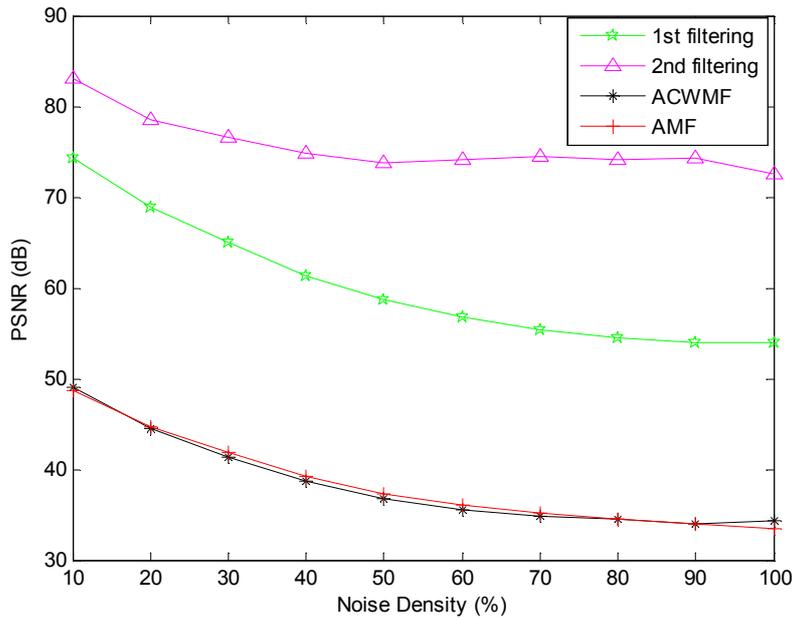


Figure 7. Plot of PSNR against noise density (%) for 3 × 3 windows.

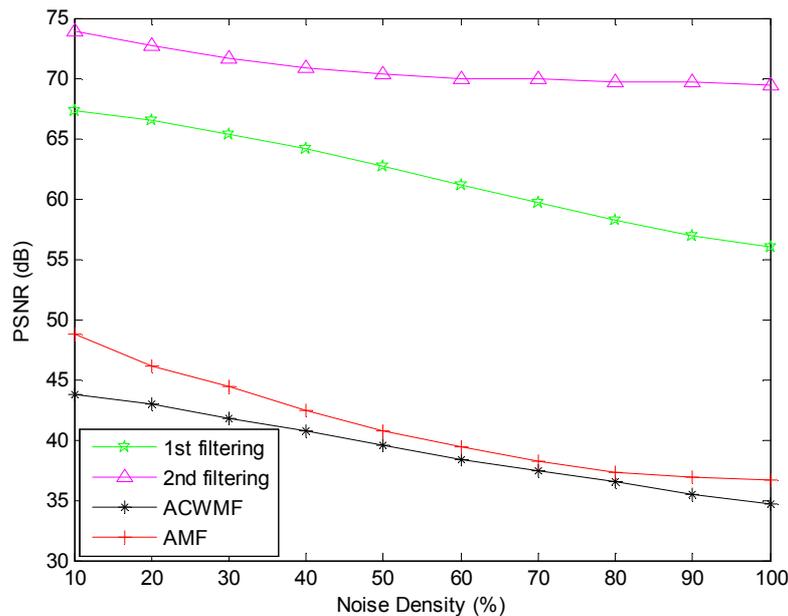


Figure 8. Plot of PSNR against noise density (%) for 5 × 5 windows.

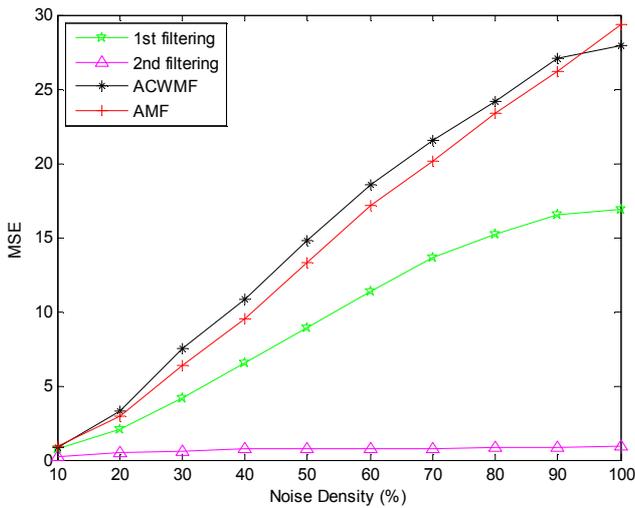


Figure 9. Plot of MSE against noise density (%) for  $3 \times 3$  windows.

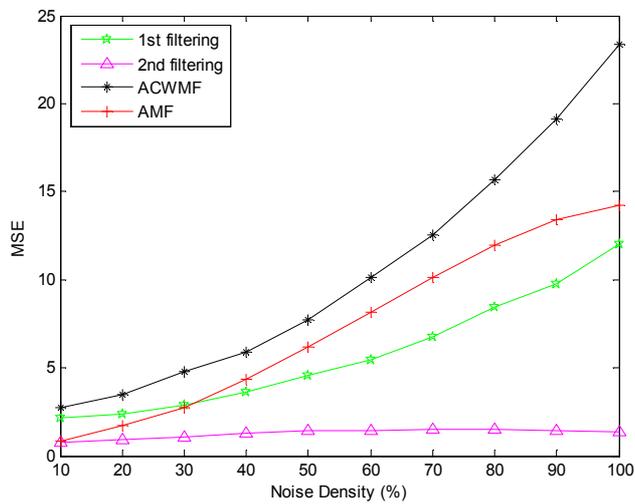


Figure 10. Plot of MSE against noise density (%) for  $5 \times 5$  windows.

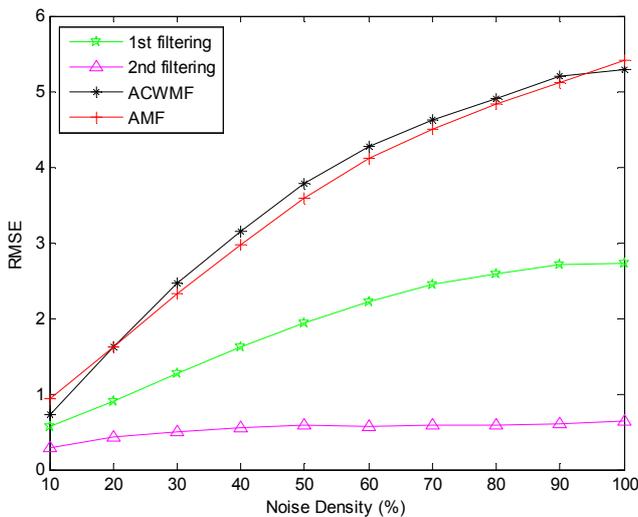


Figure 11. Plot of RMSE against noise density (%) for  $3 \times 3$  windows.

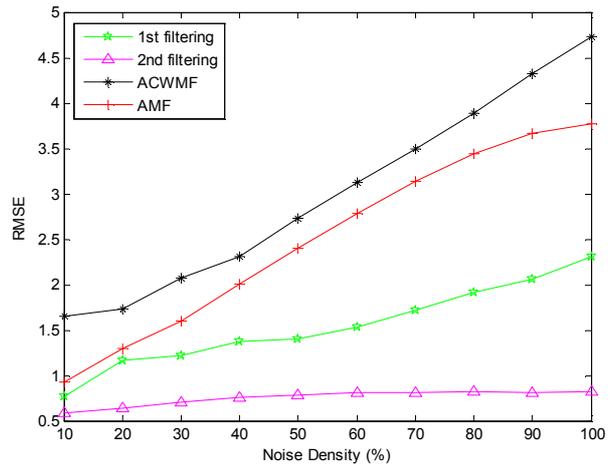


Figure 12. Plot of MSE against noise density (%) for  $5 \times 5$  windows.

The main idea of the median filter is to run through the image pixels replacing each corrupt pixel with a median of the neighbouring entries. The pattern of the neighbours is called windows which slides entry by entry over the entire signal and because in a  $3 \times 3$  windows the neighbouring pixels are few than  $5 \times 5$  window size. It was observed that at lower noise density below 20% the  $3 \times 3$  windows has a better result than  $5 \times 5$  window but as the percentage of the noise increase the performance in  $5 \times 5$  window is much better than the  $3 \times 3$  window this can be observed due to lower value of MSE in  $5 \times 5$  window than  $3 \times 3$  window in the 1<sup>st</sup> stage filtering technique, while at the second stage filtering technique the  $3 \times 3$  window perform better than the window. Studying of the filtering performance of the proposed method with some existing methods (ACWMF and AMF) by simulations on different standard images at various noise densities subsequent comparisons reveal that this proposed scheme outperforms existing schemes both in measures of signal restoration and quantitative judgement of image quality.

### 4. Conclusion

This method was able to detect the amount of impulse noise in a digital image using ANN and after the detection, a filtering algorithm is perform on the corrupted pixel which removes the impulse noise, and the image is enhanced.

### Appendix



Original image



noisy image @ 40%



2<sup>nd</sup> stage filtering

*Figure A1. Image of EEE Department Car park LAUTECH OGBOMOSO filtering using different forms of filters @ 30% noise density.*



ACWMF filtered image



Original image



AMF filtered image



noisy image @ 50%



1st stage filtering



ACWMF filtered image



AMF filtered image



1st stage filtering



2nd stage filtering

**Figure A2.** Image of LAUTECH senate building filtering using different forms of filters @ 50% noise density.

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