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COMPOSITE MEDIAN WIENER FILTER BASED TECHNIQUE FOR IMAGE ENHANCEMENT

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ABSTRACT

Image processing begins with image enhancement to improve the quality of the information existing in images for further processing. Noise is any unwanted object that affects the quality of original images. This always happened during the acquisition of images, which cause gaussian noise via photoelectric sensor. Also, impulse noise as well is introduced during transferring of some images from one place to another because of unstable network. Hence, these noises combine to form mixed noise in some images, which change the form and loss of information in the images. Filtering techniques are usually used in smoothing and sharpness of images, extraction the useful information and prepare an image for analysis processing. In this research, a novel technique of hybrid filter for enhancing images degraded by mixed noise has been exhibited. The proposed model of the novel filter uses the concept of two element composite filter. This technique improved the fusion of Median filter and Wiener filter to eliminate mixed form of noise from digital image created during image acquisition process. Composite Median Wiener(CMW) is not two filters in series, yet it can remove the blurredness, keep the image edges, and eliminate the mixed noise from the image. The result of CMW filter application on noisy image shows that it is an effective filter in enhancing the quality image.

Keywords: *Median Filter, Weiner Filter, Image Enhancement, CMW Filter, Peak Signal-to-Noise Ratio (PSNR)*

1. INTRODUCTION

Obtaining accurate information from digital image has become major challenge of image processing and analysis nowadays. Many images have lost their information because of noise. Many researchers have taken up this challenge and working on the noise removing filters for image enhancement. Lakshmi et al. (2012) [1] was able to work on removing the impulse noise using modified trimmed median filter. This technique has not been able to give good result at very high noise density, and only remove impulse noise in an image. Kamalaven, et al (2015) [2], proposed image denoising using Perona-Malik variation with different edge stopping function. However, the method has not taken care of mixed noise. Reddy et al (2012) [3] use hybrid filters for medical image enhancement. The hybrid filter techniques were designed and executed serially, which make it two filters. Hence, there is elongation of processing time. Table I illustrate more image enhancement techniques and their limitations

Table 1: Existing Image Enhancement Techniques

Ref.	Research Topic	Technique	Limitation
[4]	The Effect of The Wiener and Median Filler for Image Noise Removal	Wiener filter and Median filter	Hybrid (Serial) No Evaluation
[5]	Image Enhancement by Hybrid Filter	Median filter and Wiener Filter	Hybrid (Serial)
[6]	Image Enhancement using Hybrid Filtering Technique	Unsharp Mask filter and Median filter	Hybrid (Serial)

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[7]	Adaptive composite filters for pattern recognition in nonoverlapping scenes using noisy training images	Bank of filters	Complex filtering
[8]	An Improved Approach of Image Enhancement Using Fusion Technique	Median filter and Weiner filter	Hybrid (Serial)
[9]	Image De-Noising by Using Median Filter and Weiner Filter	Median filter and Weiner filter	Hybrid (Serial)
[10]	Algorithm for De-noising of Color Images based on Median Filter	Median filter	Single filter
[11]	Fingerprint image enhancement using Median Sigmoid filter	Median Sigmoid (MS) filter	Fingerprint domain only
[12]	Hybrid approach for noise removal and Image enhancement of brain tumors in Magnetic resonance images	Anisotropic Diffusion Filter with Modified Decision Based Unsymmetric Trimmed Median Filter	Hybrid (serial)

This paper work on drawback of existing techniques by fusing two filters of distinct type to remove mixed noise using composite concept. The concept of composite filters (CF) is a fusion of at least two wellsprings of compatible dynamic information [13]

The photoelectric of capturing sensor introduces White Gaussian as noise into the image during acquisition. This type of noise can be removed by using the well-known filter known as Wiener filter. Then again, the addition of impulse noise to the image during the unstable transferring of network cause the loss of some image data. Median filter is an effective commonly filter out of many designed filters used in removing impulse noise. However, Wiener filter or Median filter alone cannot proficiently remove or reduce this mixed noise [14]. Hence, this sparks motivation among research culture to investigate and propose a new filter to remove the mixed noise in an image.

Noise is an unwanted information which changes the image quality. It is generated during image acquisition process due to imaging sensors, affected by ambient conditions and interference which are added to an image during transmission [15, 16]. This process converts optical signals into electrical signals, by which the noise is introduced in digital images [17,18].

Noisy image is formed as follows:

$$g(x, y) = f(x, y) + n(x, y) \tag{1}$$

Where, $f(x, y)$ is the original image pixel; $n(x, y)$ is the noise term; and $g(x, y)$ is the resulting noisy pixel.

The noise model is for the utmost kinds of noise such as salt-and-pepper noise and gaussian noise. Noisy image could be restored to quality image based on the estimation of noise model.

1.1 Salt-and-Pepper Noise

Salt-and-pepper noise is a noise model that has two likely values of *"a"* and *"b"* with probability of each value is less than 0.1. If the value is higher, the noise will immensely control the image. In case of 8-pixel image, the distinctive value for pepper and salt noise are close to 0 (minimum corrupted pixels) and 255 (maximum corrupted pixels) respectfully [19, 11]. These corrupted or dead pixels will cause an image with salt and pepper noise to have black and white spots on it. The salt-and-pepper noise is generated due to camera's sensor cells malfunctioning, failure of memory cell or synchronization errors in the image transmission or digitalization. The probability model of this salt and pepper noise is shown in Figure 1.

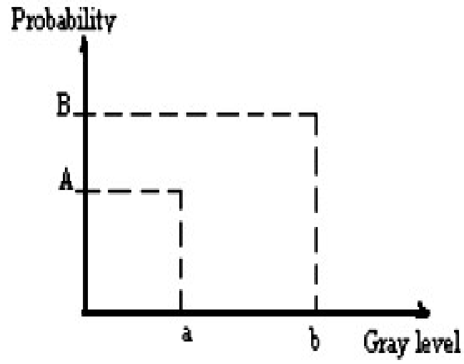

Figure 1: Salt-and-Pepper Noise Probability Density Function Model.

The plot in Figure 1 can be developed using the following equation,

$$PDF_{salt\&pepper} = \begin{cases} A & for \quad g=a("pepper") \\ B & for \quad g=b("salt") \end{cases} \qquad (2)$$

Where, A and B are probability density function of salt-and-pepper; a and b are the two possible values of salt-and-pepper noise model.

1.2 Gaussian Noise

Gaussian noise is a noise that is independent at each pixel and signal intensity, thus the values are randomly added to the image matrix. Gaussian noise is valuable for natural modeling procedures that introduce noise. For instant, noise caused by the discrete idea of radiation and the transformation of optical signal into an electrical one, that is detector or shot noise. The electrical noise transform, during acquisition to sensor electrical signal amplification, and so on [19]. Figure 2 shows the model for Gaussian noise.

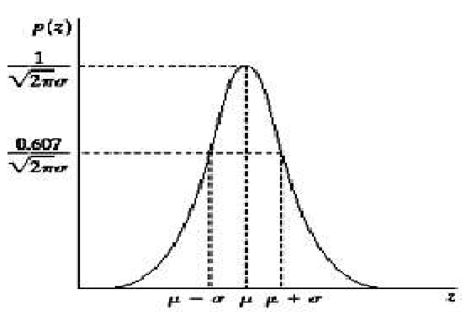

Figure 2: Gaussian Noise Probability Density Function Model

Probability density function model can be plotted using the following equation,

$$PDF_{Gaussian} = \frac{1}{\sqrt{2\pi\sigma}} \ell^{-\frac{(g-\mu)^2}{2\sigma^2}} \qquad (3)$$

Where,

g = *gray level;*
μ = *mean;*
σ = *standard deviation*

2. IMAGE ENHANCEMENT

Image enhancement is an essential stage of image processing. It improves the contrast and normalize an image [20]. Therefore, it is very indispensable to apply noise removal algorithm to enhance the quality of the degraded image [21]. The algorithm can be linear or non-linear [22]. In image processing, various filtering techniques such as Spatial Domain Method and Frequency Domain Method are obtainable to enhance the quality of images.

Spatial domain methods directly manipulate pixels' values and uniformly enhance the image [23]. However, this technique might produce undesirable images because it cannot be selective, especially in enhancing edges or other required information. However, despite its simplicity, it is not effective. Logarithmic transforms, power law transforms, or histogram equalization are among the transformations in this method. Median filter is categorized under this technique.

Frequency domain method on the other hand, involves retransformation of image frequency back to the spatial domain. Thus, the image is easily enhanced. There are several domains of frequency transform such as discrete cosine, discrete transform, and Hartley Transform [24].

However, not all filters can remove the noise from images, preserve image details, and enhance the quality of image. For image analysis, there is a need for quality image, which is obtainable from good image enhancement technique [25]. Figure 3 shows the main processes in image enhancement.

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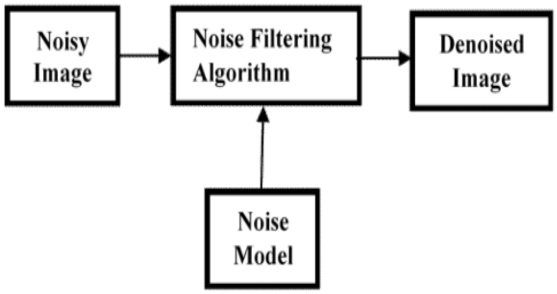

Figure 3: General Noise Removal Process

The noise removal process as depicted in Figure 3 starts by applying algorithm of image enhancement model, to finally obtain a clear and sharp image, without or lack of noise. Details on filtering techniques/approaches are described in the following sections.

However, noise is undesirable segment of image that increase the size of original image because they are additional content. The procedure of the making noisy image is as follow:

Algorithm I: Noisy Image Algorithm

Require: Image

Ensure: Noisy Image

1. Read-in an image
2. Convert image in (1) to gray scale image
3. Add “salt & pepper” noise to image in (2)
4. Add “gaussian” noise to image in (3)
5. Obtain noisy image

2.1 Median Filter

Median Filter [26, 27] is a non-linear filter. It is based on order statistics. Many studies have proved that Median filter is more capable of eliminating salt and pepper noise with reasonable computational algorithms. Nevertheless, it has discrediting regions like the original image, which serves as its drawback [28]. It is used to reduce the amount of intensity variations between two pixels.

The algorithm for the Median filtering implementation can be described as follows:

A filter mask (3 × 3) that consist of 8-neighbourhood with the center of (i,j) is used. Suppose, A is the input image obtained after the pre-processing, F is the 3 × 3 moving filter mask, and M is the output image. The pixel values in the 8-neighbourhood filter mask are sorted in ascending order by using Equation 4. The median is computed by sorting all values of pixel in ascending order and replaced the pixel that is calculated by the middle value of pixel. Suppose the neighboring pixel of image to consider is an odd number of pixels, then, there will be replacement of the middle pixel values as shown in Figure 4. Hence, median value is determined by using Equation 5. The value of $M_{i,j}$ is then replaced by the obtained median value. This action is done by using Equation 6.

$$A = \begin{array}{|c|c}\hline a_{11} & a_{12} \\ \hline a_{21} & a_{ij} \\ \hline \end{array}$$

Figure 4: The median of pixel value of 8-neighborhood

For every point selected in the neighbouring pixel of (3 × 3) image,

$$A = a_{11} \cdots a_{ij} \cdots a_{mn} \tag{4}$$

Where i = 1,2,3,….m; j = 1,2,3,….n,; m=n=3,5,7

$$Order(A) = \hat{a}_{11} < \ldots < \hat{a}_{i-1,j-1} < \hat{a}_{ij} < \hat{a}_{i+1,j+1} < \ldots < a_{mn} \tag{5}$$

Hence,

$$M_{i,j} = \hat{a}_{i,j} \tag{6}$$

Where $M_{i,j}$ is the Median.

2.2 Wiener Filter

Wiener filter is a statistical based approach filtering technique. Hence, it is characterized that signal noise and additive white gaussian noise are stationary linear random processes with known spectral characteristics. The Wiener filter is a filter that filters image from diverse viewpoints. The technique is to have acquaintance of the original signal and the noise properties [25, 29, 30].

The major objective of the Wiener filter is to remove the noise that has degraded an image.

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The Wiener filter evaluates the mean and variance around each pixel such that:

Mean

$$\mu(A) = \frac{1}{mn}\sum_{i}^{m}\sum_{j}^{n} a_{i,j} \tag{7}$$

And Variance

$$\sigma^2(A) = \frac{1}{mn}\sum_{i}^{m}\sum_{j}^{n} a_{i,j}^2 - \mu^2(A) \tag{8}$$

Forming Wiener filter equation from combining Mean Equation and Variance equation together in Equations 7 and 8; hence we have equation 9, such that:

$$W_{i,j} = \mu(A) + \frac{\sigma^2(A) - v^2}{\sigma^2(A)}(a_{i,j} - \mu(A)) \tag{9}$$

Where,

Wij is Wiener

μ is the mean

σ is the variance around each pixel.

v^2 is the noise variance

3. PROPOSED TECHNIQUE

This paper proposes an image enhancement technique called Composite Median Wiener (CMW) filter. This technique is a fusion of Median filter and Wiener filter. The technique aims to eliminate salt-and-pepper and gaussian noise, which form mixed noise from the acquired image and to enhance the image to the suitable level of contrast [25]. Enhancement and restoration techniques are to remove noises, amend fragmented up ridges, cleaning up ridge valleys, and increasing the contrast between ridges and valleys in the gray scale images [31]. Contrast of the image also plays significant role in determining the quality of the image apart from noise removal [32]. The existing hybrid filter is either executed serially, where one filter executed one after another or having the knowledge of a noise to remove. However, MW filter is a single filter that can remove mixed type of noises. The framework of CMW filter technique is shown in Figure 5.

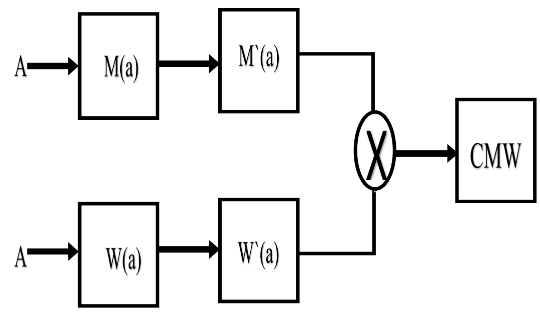

Figure 5: Framework of CMW filter technique development

CMW filter was developed by fusing Median filter and Wiener filter as shown in Figure 5. To come up with CMW filter computation, a modification is done towards Median filter and Equation 6 is composited with Equation 9 to form the Composite Median Wiener (CMW) filter equation, presented in Equation 10.

$$CMW_{i,j} = \mu(\tilde{A}) + \frac{\sigma^2(\tilde{A}) - v^2}{\sigma^2(\tilde{A})}\left[M_{i,j} - \mu(\tilde{A})\right] \tag{10}$$

Where,

CMWij is Composite Median Wiener
Mij is Median
μ is the mean
σ is the variance around each pixel.
v^2 is the noise variance
$\tilde{A}$ is order of input image

Equation (10) is the new formula developed for proposed image composite filter called CMW filter, which applies upon the input target image pixel by pixel for image enhancement. The proposed algorithm for CMW filter is given in Algorithm II.

4. EXPERIMENTAL SETUP

The original image is modelled to noisy image with mixed noise using Equation 1. The original image served as a reference parameter during image enhancement quality assessment. The Median filter algorithm was applied on noisy image based on Equation 6, while Wiener filter algorithm was applied on noisy image based on Equation 9. Median filter and Wiener filter were applied serially on noisy image, while the proposed filter, CMW filter was applied to noisy image based on

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Equation 10. The framework evaluation for the proposed CWM filter application for image enhancement in Figure 6 is built on general noise removal process as shown in Figure 3.

Algorithm II: The Proposed Method Algorithm

Require: Gray Image
Ensure: Enhanced Image

1. A 2-D mask gray scale image is selected
2. Pre-allocate another matrix of same size with zero
3. Make a window matrix of size 3 x 3 with the elements of input matrix
4. Transfer the window matrix to an array
5. Sort the window and name it as sorted window
6. Assign values to the variables for Min, Max, & Median
7. Check for any type of the noise present in window
8. Apply mean value of the neighboring pixels, which are the noise free values
9. Perform Median-Wiener operation on the noisy pixel value in the image
10. Compute the PSNR and MSE and display the filtered image

4.1 Image Quality Assessment

Images quality assessment can be categorized into two basic classes. They are mathematically defined measures and human visual system. The root means square error (RMSE) and signal to noise ratio (SNR) are mathematically defined measures, while perceptual quality measures are referred to the human visual system (HVS). However, the mean square error (MSE) and peak signal to noise ratio (PSNR) are the two most commonly used methods in the mathematically defined measures. The reason lies in their simplicity of implementation. Moreover, the mean square error (MSE) takes care of error sensitivity methods [33].

The filtered images were evaluated using Peak Signal-to-Noise Ratio (PSNR) and Mean Squared Error (MSE) [34]. MSE is the cumulative mean square error between original image and the filtered image. For images x and y, x is taken to be original image while y is taken to filtered image; hence MSE could be computed using Equation 11.

$$MSE(x,y) = \frac{1}{N}\sum_{i=1}^{N}(x_i - y_i)^2 \qquad (11)$$

Where,

N = total number of pixels in an image

i = initial value of pixel in an image

x_i = original image

y_i = restored image

Normally, the MSE is expressed as the peak signal to noise ratio (PSNR) measure. PSNR is the estimation standard evaluation of the restored image quality. It is known to be the ratio between maximum possible power of a signal and the power of distorting noise which affects the quality of its representation. PSNR represents an estimate of peak value of the error. Hence, PSNR can be computed with Equation 12.

$$PSNR = 10\log_{10}\left(\frac{L^2}{MSE}\right) \qquad (12)$$

Where, L is the maximum fluctuation in the input image. Input image having double-precision floating-point data type. L have the range value of 1 to 255 such that 255 is the maximum value of input image with an 8-bit unsigned inter data [35].

5. RESULTS AND DISCUSSION

The experiment was carried out on eight noisy images with noise conditions called noise density. The noise contains salt and pepper value and gaussian value. The original eight images were used for trained filter and the image was corrupted with noise. The efficiency and the performance of all the filters and the proposed algorithms were tested on dimensional (2-D) gray scale image of Eight image with noise density, which range from 0.01 to 0.09 and 0.01 to 0.03 of salt & pepper noise and additive white gaussian noise respectively.

The visual results are shown in Figure 6 as various filters and proposed filtering applied on noisy image. Figure 6a is the original image while figure 6b shows noisy image with noise density of 0.01 of salt & pepper noise and 0.02 noise density of additive white gaussian noise. Figure 6c shows effect of Median filter on the noisy image and figure 6d is output when Wiener filter applied on the noisy Eight image. Median filter and Wiener filter was applied serially on the noisy image and

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produced the figure 6e. In order way round, the Wiener filter and Media filter also was applied serially on the same noisy image and figure 6f in the out, while the proposed single filter of Composite Median Wiener (CMW) filter was applied on the same noisy filter and figure 6g is the output.

The PSNR was used to compare the proposed filter (CMW filter) against other filters. The evaluation on framework of the proposed CMW filter against Median filter, Wiener filter, Median filter and Wiener filter, and Wiener filter and Median filter using PSNR is shown in Figure 7.

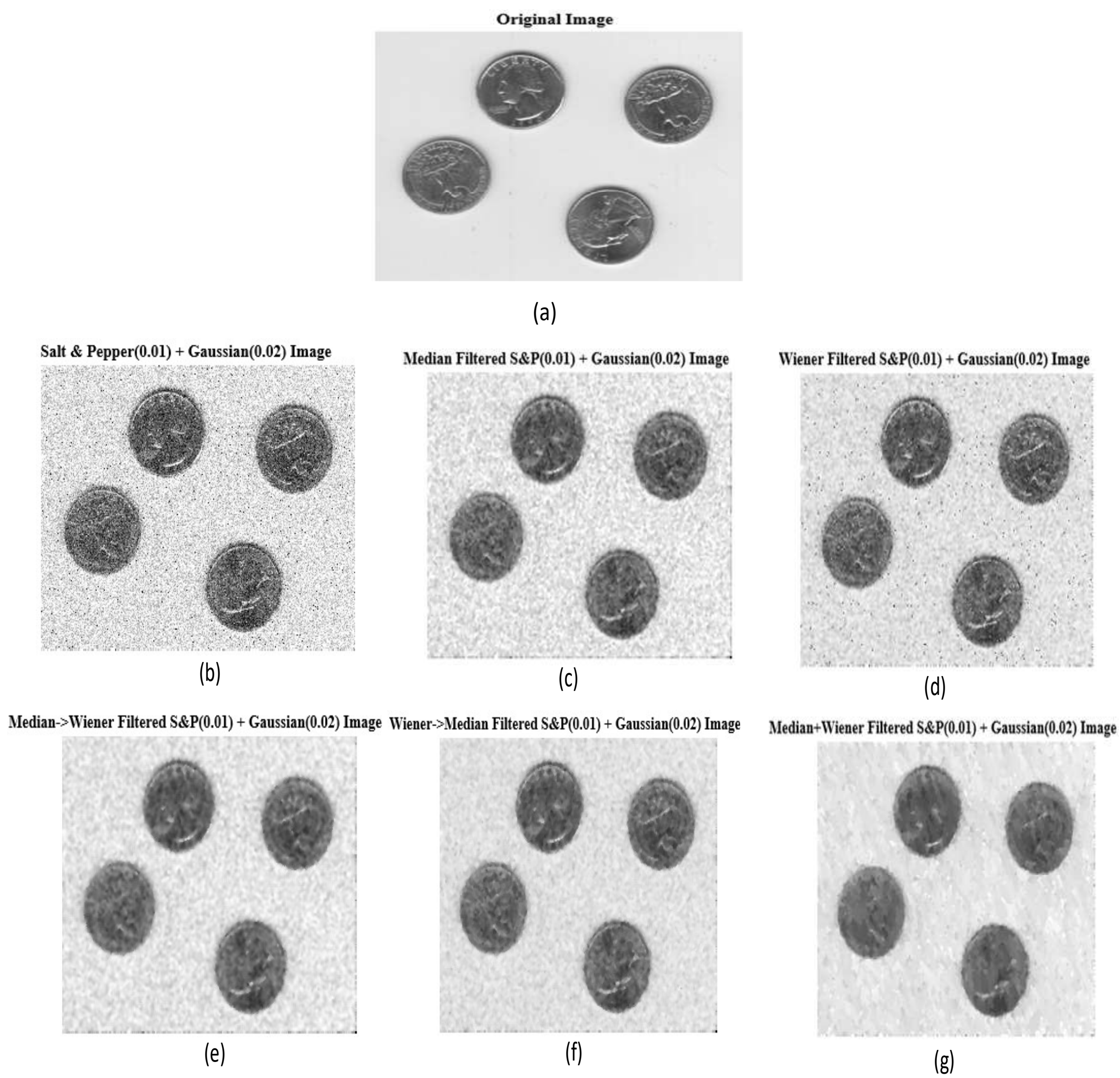

Figure 6: The visual results of filters on eight noisy images

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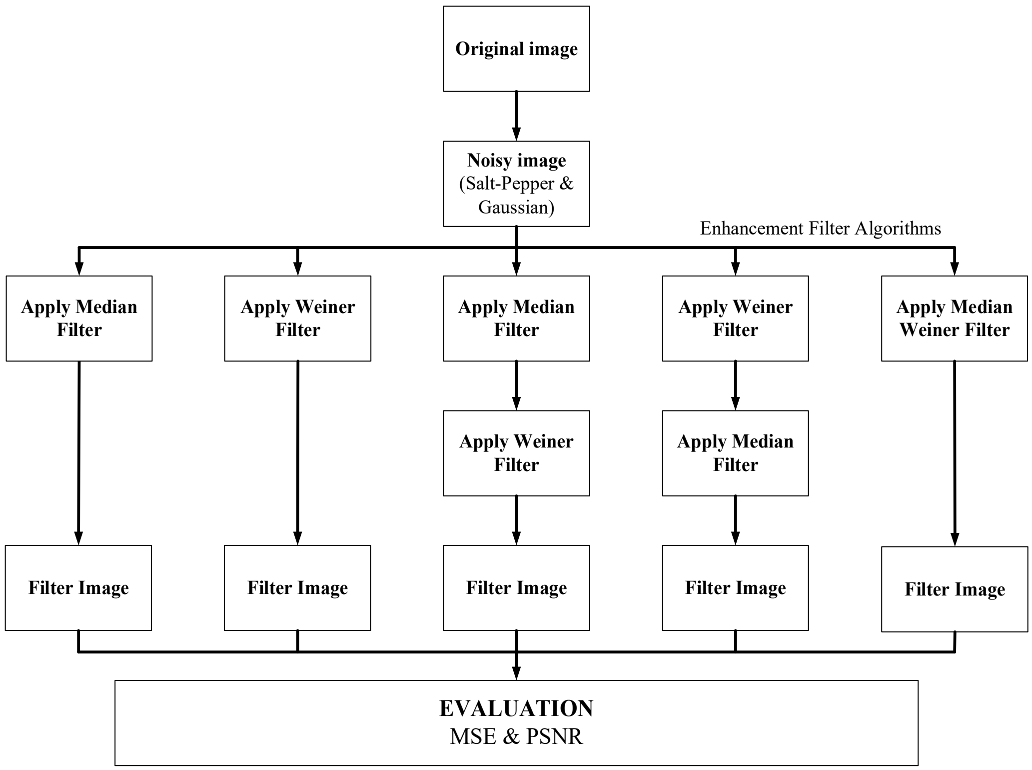

Figure 7: Proposed framework for evaluating CMW filter

Table II: PSNR values for CMW Filter and other Filtering Techniques

Iteration	Noise Density		Noisy Image	Median Filter	Wiener Filter	Median->Wiener Filter	Wiener->Median Filter	Median-Wiener Filter
	salt pepper	gaussian						
1	0.01	0.01	19.3177	25.5717	23.8401	27.1780	27.0100	27.7503
2	0.01	0.02	16.1104	22.2447	21.7217	24.6321	24.2862	25.0031
3	0.01	0.03	13.7337	19.8519	19.1713	21.8538	21.4905	22.9771
4	0.03	0.01	17.3008	25.4203	20.8741	27.1100	26.8961	27.3767
5	0.03	0.02	15.1913	22.1916	20.2091	24.3696	24.3696	25.0171
6	0.03	0.03	13.3034	19.7689	18.5399	21.7692	21.2358	22.7709
7	0.05	0.01	16.1060	25.2442	19.6662	26.7909	26.7054	27.0028
8	0.05	0.02	14.4781	21.9494	19.2973	23.9910	23.8640	24.7158
9	0.05	0.03	12.8767	19.5165	17.9617	21.4505	20.8333	22.5664
10	0.07	0.01	15.0897	25.0122	18.7916	26.4979	26.2213	26.9097
11	0.07	0.02	13.8562	21.8297	18.5617	23.8698	23.4493	24.7660
12	0.07	0.03	12.5075	19.3960	17.5324	21.3318	20.5113	22.5650
13	0.09	0.01	14.2645	24.5776	18.2382	25.9907	25.4527	26.4951
14	0.09	0.02	13.3230	21.4991	18.0764	23.4737	22.8962	24.3895
15	0.09	0.03	12.1557	19.0878	17.1204	20.9369	20.0614	22.2445

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The simulation results of the experiments are shown in Table 1. The Spread sheet of Microsoft Excel software package is used in analyzing of Table 1and the comparison chat is of each technique performance is shown in Figure 8.

From Table 1, at iteration 1 when the density of noise contains 0.01 for salt-pepper and gaussian respectively, the PSNR value of Composite Median Wiener filter is the highest with 27.7503. The value of serial operation of Median filter follow by Wiener filter is 27.1780, while the serial operation of Wiener filter follow by Median filter is 27.0100. The conventional Wiener filter has the least value, which is 23.8401. The higher the PSNR value, the better is the filter technique used for that image enhancement. Hence, the value of MW filter is the highest followed by the serial technique application of Median filter and Wiener filter, and the serial technique application of Wiener filter and Median filter. The PSNR value of Median filter in enhancing

image is better than that of Wiener filter. Figure 8 interprets Table 1 at a glance.

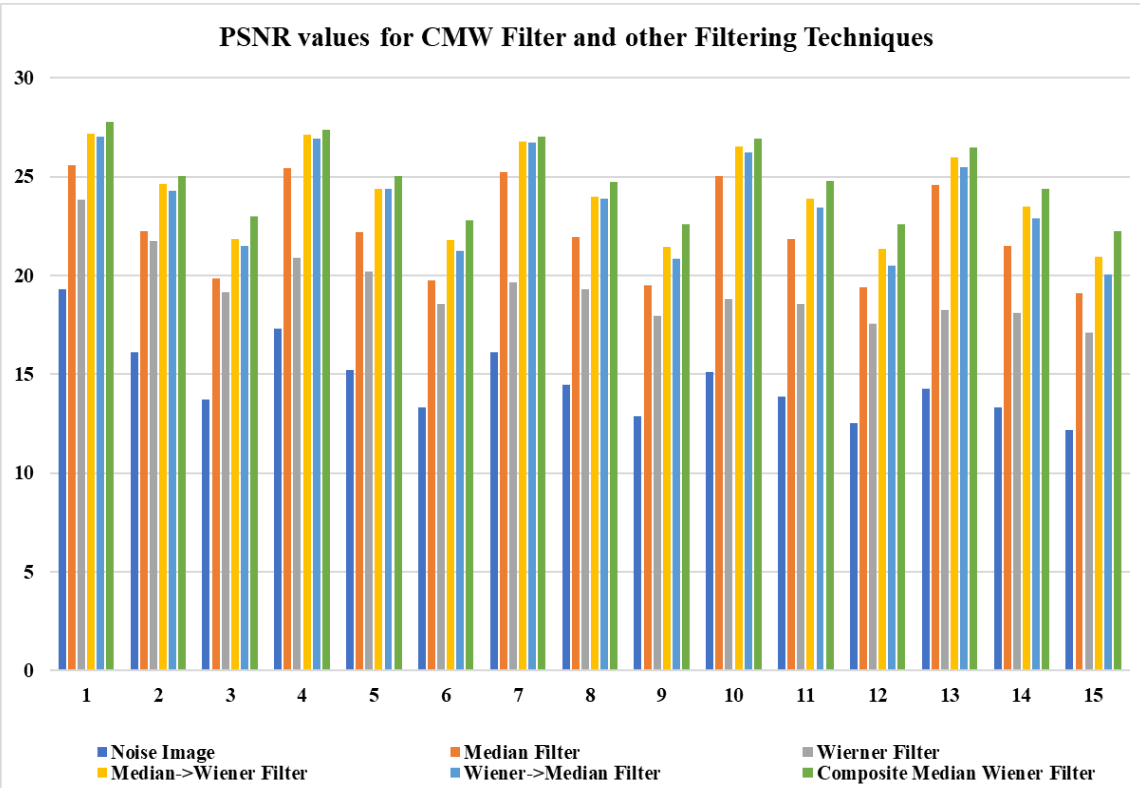

Figure 8: PSNR values for MW Filter and other Filtering Techniques

Figure 8 compares PSNR values for CMW filter technique and other filtering techniques. From the figure, Composite Median Weiner filter technique proved to enhance the image better compared to the other set of filters. This is followed by Median -> Weiner filter (a hybrid process in which Median filter its operation follows by Weiner filter), and Weiner -> Median filter (a hybrid process in which Weiner filter its operation follows by Median filter). This means, the use of Median on top of Weiner works better. This might due to the function of Median filter to remove the remove salt and pepper noise. thus, if this noise is reduced, any types of filter that follows or integrated will bring a more enhanced image(s).

6. CONCLUSION

Salt and pepper noise, and Gaussian noise are brought together to form mixed noise and added to the original image, which were simulated to noisy images. A novel composite filter, which is Median Wiener (CMW) filter for removing mixed noise from an image is developed. The ultimate dominance of the proposed filter above other filters is that it can remove mixed noise from images while preserving thin lines and edges in the original image. Both quantitative and qualitative performance measure were performed using the proposed technique. Visual Quality is the qualitative measure used while the peak signal-to-noise ratio (PSNR) is used as a quantitative measure. Experimental results demonstrate that the proposed CMW filter technique approach outperforms several existing algorithms that perform its operation serially. However, this work only used composite filter of 2-element form. The concept can be extended to 3-element form or more for further research. Also, the CMW filter technique was simulated with an image in this work, it can also be applied to any other noisy images.

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