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High noise Removal Using Weighted Median Filter of Salt-and-Pepper Noise

Hiba-Alla Tariq Abdullah [1]
Northern Technical University,Engineering Technical College -Mosul- Iraq

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Corresponding author:
Name: Hiba-Alla Tariq
Affiliation : Northern Technical University
Email: hibatallahtariq@ntu.edu.iq

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ABSTRACT

The objective of this study is to determine whether or not the median and weighted median filters are efficient in removing salt and pepper noise from digital photographs. The picture quality may be severely diminished when there is a high degree of this noise. Because of its ease of use, efficiency, and capacity to maintain edge details, the median filter is often used for the purpose of noise reduction. On the other hand, it is less effective in environments that are notoriously loud. As an additional, more sophisticated option, the study recommends using a weighted median filter in order to circumvent this issue. By assigning greater weight to pixels with comparable intensity levels, this filter is extremely good at decreasing background noise. As a result, it is highly ideal for use in contexts that possess a high degree of background noise. According to the findings of the experiments, the suggested approach works much better than the conventional median filtering strategies when used to high-noise circumstances.

Introduction

Images are always polluted by noise during image acquisition and transmission, resulting in low-quality images. Thus, it is necessary to remove the noise before using the images for subsequent analysis tasks. A very common type of image noise is the so-called salt and pepper noise, which is scattered throughout the image and consists of only the maximum or minimum intensity values (i.e., 0 or 255) in the dynamic range. Generally, the removal of salt and pepper noise consists of two problems: (1) how to detect the noisy pixels and (2) how to repair them.

The practice of applying algorithms to digital images is known as "digital image processing." It belongs to the category of digital signal processing. It may have the following benefits: During processing, a variety of techniques are used to reduce noise and signal distortion in the input data.

A variety of approaches are used for image processing. These methods, which were established in the 1960s, were applied mainly to character recognition, medical image analysis, and wire photo applications. However, the high expense of these methods made them disadvantageous. Then, in the 1970s, more affordable methods such as computers and specialized hardware became accessible. The only restriction found was the conversion of television standards after real-time image processing. Finally, In the 2000s, digital image processing primarily became the most extensively utilized method of image processing due to the advent of faster computer generations and processing units. Since it is the most economical approach as well as the most multilateral [2][3]. Later, further techniques were developed. One example is the employment of wavelets in [4]'s new phase congruency calculation approach. Phase congruency in 2D images can be calculated by extending a 1D signal. For varied scales of images, high pass filters are utilized. On the other hand, the brand-new Bayesian picture de-noising technique with two complementary discontinuity measures was introduced in [5]. His study's results demonstrate that noisy pictures may be created with a clear, high peak signal to noise ratio (PSNR), and that the noise can be successfully decreased while keeping edge components. For feature preservation, the spatial-gradient and another metric that looks at continuity detects contextual discontinuities. The most of solutions up to now have had the drawbacks of being expensive, complicated, and blurring out features in the image. This paper suggests an image de-noising method in the spatial and wavelet domain to get beyond these restrictions. De-noising images in the wavelet and spatial domains tend to use local mean filters, mean filters, and wavelet thresholds to eliminate noise.

Image noise usually occurs during signal acquisition and transmission. Image denoising is a procedure of removing noise from an image. The primary purpose of image denoising is to preserve image structures such as details, edges,

and textures. The images acquired after denoising are used for post-processing tasks such as image segmentation, feature extraction, image analysis, image classification, and pattern recognition. Noise removal with image structure preservation is vital for improving the accuracy and performance of other post-processing tasks [6] [7].

The fixed-value and random-value types of impulse noise distributions are the most common. In impulse noise with a fixed value, a noise pixel takes either a max value of 255 or a min value of 0. Another name for impulse noise is salt and pepper noise.

In salt and peppers noise, the noise magnitude is equally distributed in the range [0,255]. The salt and pepper noise filters were proposed in the publications as a solution to the impulse noise of fixed pixels. Regardless of whether they are for a salt and pepper noise value or numerous noises, the above filters outweigh any other impulse noise filters. As a result, the focus of this work is solely on the random value salt and pepper noise [8].

In salt and pepper noise, the intensity of pixels in the image differs greatly from that of surrounding pixels. The color of a noisy pixel has no bearing on the color of nearby pixels. There are dark and white dots in it. This noise is caused by the existence of dust inside the camera and overheated or malfunctioning Charge Coupled Device (CCD) elements [9].

Literature Review

In 2011, Houwang Zhang , Yuan Zhu and Hanying Zheng, a novel algorithm called a Nonlocal Adaptive Mean Filter (NAMF) for removing salt-and-pepper (SAP) noise from corrupted images is presented. They employ an efficient window detector with adaptive size to detect the noise. +e noisy pixel is then replaced by the combination of its neighboring pixels, and finally, a SAP noise based nonlocal mean filter is used to reconstruct the intensity values of noisy pixels. Extensive experimental results demonstrate that NAMF can obtain better performance in terms of quality for restoring images at all levels of SAP noise [10].

In 2016, Neela Chithirala, B. Natasha, N. Rubini, Anisha Radhakrishnan, introduces a new algorithm that reduces high density salt and pepper noise from images. Restoration is done by calculating the weighted mean of the nearby pixels. Weights are assigned unsymmetrically to pre-processed and unprocessed pixels. The quality was judged based on the PSNR value. The algorithm restores information for highly corrupted images. Salt and pepper noise are usually filtered with variants of the median filter. This paper provides an alternate way for noise reduction [11].

In 2018, Aswini Kumar Samantaray, Priyadarshi Kanungo, Bibhuprasad Mohanty, A novel impulse noise filter that preserves the image details and effectively suppresses high-density noise has been proposed in this work. The proposed filter works in two phases: (i) noise pixel detection phase and (ii) noise pixel restoration phase. In the detection phase, the impulse noise corrupted pixels are detected using a neighborhood decision approach. In the second phase, the true values of corrupted pixels are restored using a first-order neighborhood decision approach. Experiments are carried out with both grey scale and color images of various resolutions, texture and structures. The proposed scheme has high peak-signal-to-noise ratio and better visual quality in comparison to the standard median filter, modified decision based unsymmetrical trimmed median filter and improved fast peer-group filter with a varying noise density from 10 to 90% [12].

In 2018, Vikas Singh, Raghav Dev, Narendra K. Dhar, Pooja Agrawal, and Nishchal K. Verma, proposes a novel adaptive Type-2 fuzzy filter for removing salt and pepper noise from the images. The filter removes noise in two steps. In the first step, the pixels are categorized as good or bad based on their primary membership function (MF) values in the respective filter window. In this paper, two approaches have been proposed for finding threshold between good or bad pixels by designing primary MFs. a) MFs with distinct Means and same Variance and b) MFs with distinct Means and distinct Variances. The primary MFs of the Type-2 fuzzy set is chosen as Gaussian membership functions. Whereas, in the second step, the pixels categorized as bad are denoised. For denoising, a novel Type-1 fuzzy approach based on a weighted mean of good pixels is presented in the paper. The proposed filter is validated for several standard images with the noise level as low as 20% to as high as 99%. The results show that the proposed

filter performs better in terms of peak signal-noise-ratio values compared to other state-of-the-art algorithms [13].

In 2020, Dang N. H. Thanh1, Nguyen Ngoc Hien, et-al proposed Adaptive Switching Weight Mean Filter (ASWMF) to remove the salt and pepper noise. Instead of using median or mean, ASWMF assigns value of a switching weight mean (SWM) to grey value of the center pixel of an adaptive window. SWM is evaluated by eliminating all noisy pixels from the adaptive window and putting a low weight for pixels on the diagonals and a high weight for pixels outside the diagonals. ASWMF can remove noise with various noise levels effectively. It not only successes for low-density denoising, but also removes medium-density and high-density noise impressively. In experiments, they compare denoising results with other similar denoising methods. According to intuition as well as error metrics such as the peak [14].

In 2023, MeixiaWang, Susu Wang, Xiaoqin Ju and Yanhong Wang, presents a set of algorithms that are effective in removing salt-and-pepper noise from images with high efficiency. This type of noise is a type of image noise that appears as randomly distributed white and black pixels in an image, and it affects individual pixels in an image, causing them to have either the highest intensity value (white pixel) or the lowest intensity value (black pixel). The basic idea of these methods is to introduce a new weighted average based on a well-known idea in fractional calculus, called the Atangana–Baleanu fractional integral operator. Moreover, the concept of symmetry is clearly used in the proposed window mask structures in this paper. Furthermore, their proposed method has been extensively tested on various datasets to assess its effectiveness in denoising images. They compared their method with other state-of-the-art denoising techniques and found that it outperformed them in terms of the (PSNR) metric and visually as well. Their proposed methods are advantageous over other methods in image denoising because they are computationally efficient and can be easily implemented [15].

In 2023, Turki M. Alanazi, Kamel Berriri, introduces a new method for real-time high-density impulsive noise elimination applied to medical images. A double process aimed at the enhancement of local data composed of Nested Filtering followed by a Morphological Operation (NFMO) is proposed. The major problem with heavily noisy images is the lack of color information around corrupted pixels. They show that the classic replacement techniques all come up against this problem, resulting in average restoration quality. They only focus on the corrupt pixel replacement phase. For the detection itself, they use the Modified Laplacian Vector Median Filter (MLVMF). To perform pixel replacement, two-window nested filtering is suggested. All noise pixels in the neighborhood scanned by the first window are investigated using the second window. This investigation phase increases the amount of useful information within the first window. The remaining useful information that the second window failed to produce in the case of a very strong connex noise concentration is then estimated using a morphological operation of dilatation [16].

Proposed Method

The median filter was used with different noise ratios. Salt and pepper were used to test the accuracy of the algorithm. Classic datasets - Pepper, Barbara, and Cameraman - were selected from the original image input, followed by a process of adding salt and pepper to make a noised image. On the other hand, the noise was removed using three types of median filter such as traditional median filter, modified median filter as well weighted median filter for high density denoising using the results of two equations for PSNR and Mean Square Error (MSE).

A conventional median filter is used to denoise images, as seen in Fig. 1. To avoid making the picture too smooth and to enhance PSNR and MSE without losing any of the original image's edges, the flow diagram for denoising images using a modified median filter is shown in Fig. 2. Figure 3 displays the flow diagram for a third approach of picture denoising when high-density salt and pepper noise is present.

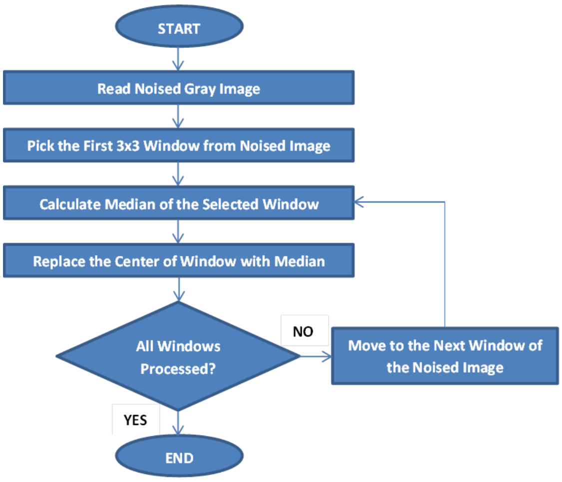


Figure 1: Flowchart of the First Method (Traditional Median Filter)

Despite the fact that the median filter effectively removes noise, it can lead to blurring or obscuring the edges and fine details of the image. This blurring effect can result in a loss of sharpness and clarity in the image, which may not be desirable in some applications where preserving image details is crucial.

Additionally, this filter is nonlinear, meaning the output pixel value is not a weighted average of the input pixel value. This non-linear nature can sometimes lead to unwanted artifacts or distortions in the processed image.

The performance of the median filter can also be sensitive to the choice of filter size or window size. Choosing an inappropriate filter size can either over-smooth the image, leading to loss of detail, or under-smooth it, failing to effectively remove the noise.

In terms of time, the median filter can be computationally intensive, especially for larger filter sizes or high-resolution images. This can result in increased processing time, which may be a concern for real-time or high-speed image processing applications.

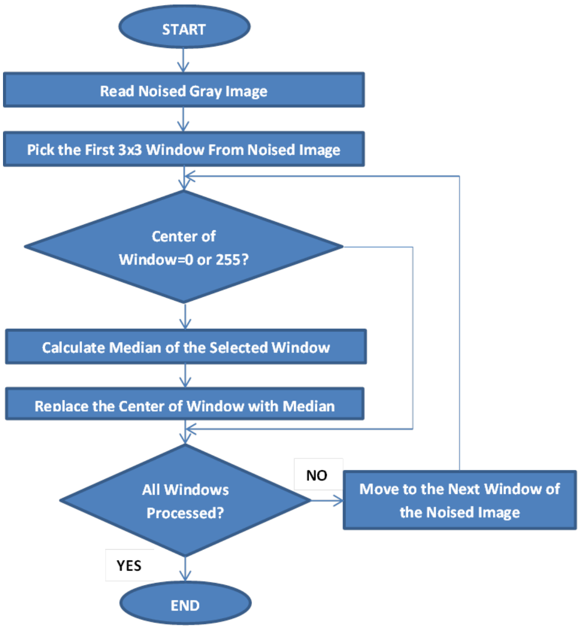


Figure 2: Flowchart of the Second Method (Modified Median Filter)

Unlike the median filter, which blurs the image and can lead to a loss of image details, the modified median filter can preserve more image details while still reducing noise. This makes it more suitable for applications where retaining sharpness and clarity is important.

The modified median filter effectively reduces noise in the image without introducing significant blurring. It can handle different types of noise, including Gaussian noise and salt-and-pepper noise, more effectively than the standard median filter. This filter is designed to better preserve edges and boundaries in the image. It can smooth noise while maintaining the sharpness of edges, resulting in a more visually pleasing and natural-looking image.

While the modified median filter may be slightly more computationally intensive than the standard median filter due to its adaptive nature, it is still relatively efficient and can be implemented in real-time or near-real-time applications with reasonable processing times.

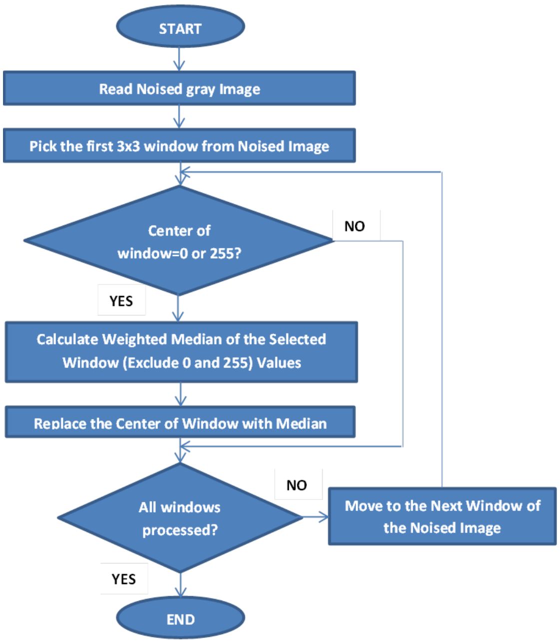


Figure 3: Flowchart of the Third Method (Weighted Median Filter)

The third method has several advantages that match those of the second method, but in addition, it gives much better results when the noise level is very high, i.e., more than (3%). The success rate of this method in processing noisy images can reach up to 90%, where the number of pixels equal to (0 and 255) in a single window exceeds half. For example, in a window size of (3x3), the number would be 5 or more, and in a window size of (5x5), the number would be 13 or more, and so on.

This method is very effective in removing salt-and-pepper noise, although the values of (PSNR and MSE) are not ideal. However, the image appears very clear with some distortions at the edges, especially for images with very high noise.

Results

The quality of images resulting from different algorithms is measured using various criteria. One of these criteria is the calculation of the (PSNR), which can be measured by the following formula:

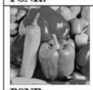
$$MSE = \frac{\sum_{M,N} [I_1(m,n) - I_2(m,n)]^2}{M * N} \qquad \dots (1)$$

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

PSNR measures the difference between the original image and the denoised image in terms of their peak signal power and noise power. Higher PSNR values indicate better image quality. Moreover, MSE measures the average squared difference between the original and denoised images. Lower MSE values indicate better image quality.

Three algorithms mentioned above has been used in denoising of Barbara, Cameraman, and peppers images contaminated with salt-and-pepper noise with intensities of 5, 25, and 50 percent as shown in Tables 1 and 2. The process flow diagram for picture denoising using a conventional median filter is shown in Fig. 1. Fig. 2 shows the flow diagram for denoising images using a modified median filter; this approach seeks to increase PSNR and MSE without losing detail or making the picture too smooth, all while keeping the original image's edges intact. The flow diagram for picture denoising using a third approach in the presence of dense salt and pepper noise is shown in Fig. 3.

Table 1. PSNR Comparison of the performance of different methods for salt-and-pepper noise ratio of 5%, 25% and 50% for the above three images.

		Noise Density=0.05	Noise Density=0.25	Noise Density=0. 5
 **PSNR:**	**Median Filter**	25.4517	22.4879	14.5735
	Modified Median Filter	33.2167	25.3454	18.1542
	Weighted Median Filter	**33.5715**	**26.759**	**22.9501**
 **PSNR:**	**Median Filter**	25.3658	21.0012	13.4311
	Modified Median Filter	31.351	24.4004	17.025
	Weighted Median Filter	**31.2839**	**25.8088**	**21.9058**
 **PSNR:**	**Median Filter**	31.6438	24.7855	14.9137
	Modified Median Filter	34.8176	25.9606	18.3417
	Weighted Median Filter	**35.2051**	**27.8935**	**24.3351**

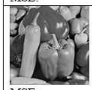
		Noise Density=0.05	Noise Density=0.25	Noise Density=0. 5
 MSE:	**Median Filter**	185.313	366.6822	2268.4726
	Modified Median Filter	31.0038	189.9078	994.6269
	Weighted Median Filter	**28.5711**	**137.1458**	**329.6636**
 MSE:	**Median Filter**	189.0154	516.3669	2951.0254
	Modified Median Filter	47.6408	236.071	1289.9631
	Weighted Median Filter	**48.3827**	**170.6877**	**419.272**
 MSE:	**Median Filter**	44.5346	216.038	2097.5423
	Modified Median Filter	21.4446	164.8223	952.6092
	Weighted Median Filter	**19.6144**	**105.6158**	**239.6487**

Table 2. MSE Comparison of the performance of different methods for salt-and-pepper noise ratio of 5%, 25% and 50% for the above three images.

Further, in Tables 1 and 2, the amount of MSE index obtained from different algorithms in the Barbara, Cameraman, and peppers images are reported. The results obtained in these tables confirm that the algorithms proposed in this article have a very impressive performance and have obtained the best results among other methods in most tests.

Our approach seems to be useful in applications where image quality is critical, such as medical imaging or surveillance. In medical imaging, for example, noise reduction in images is crucial for accurate diagnosis and treatment planning. Our method’s ability to preserve important image details while removing noise makes it an excellent candidate for these types of applications.

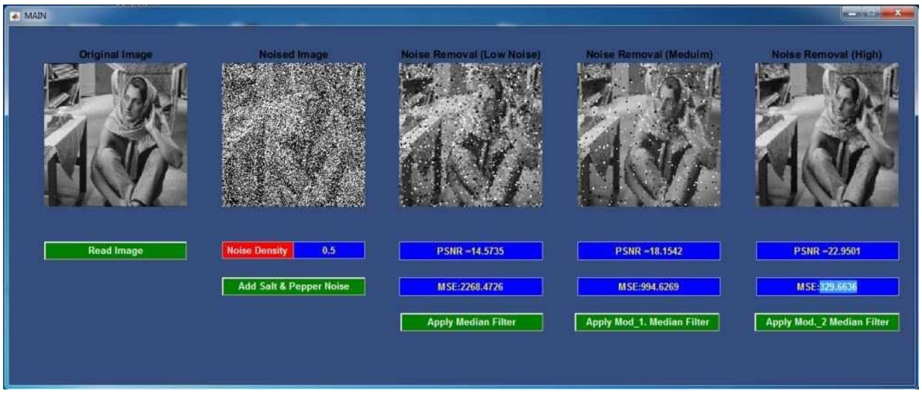
Figures 4 through 12 illustrates the method implementation in MATLAB that shows all results of the three methods for Barbara, Cameraman, and peppers images with PSNR and MSE.

```
Noise Density 0.05    PSNR =25.4517    PSNR =33.2167    PSNR =33.5715
                      MSE:185.313      MSE:31.0038      MSE:28.5711
```

Figure 4: . Noise removal for Barbara with noise Density (0.05) using three methods

```
Noise Density 0.25    PSNR =22.4879    PSNR =25.3454    PSNR =26.759
                      MSE:366.6822     MSE:189.9078     MSE:137.1458
```

Figure 5: Noise removal for Barbara with noise Density (0.25) using three methods



```
Noise Density 0.5     PSNR =14.5735    PSNR =18.1542    PSNR =22.9501
                      MSE:2268.4726    MSE:994.6269     MSE:329.6636
```

Figure 6: Noise removal for Barbara with noise Density (0.5) using three methods

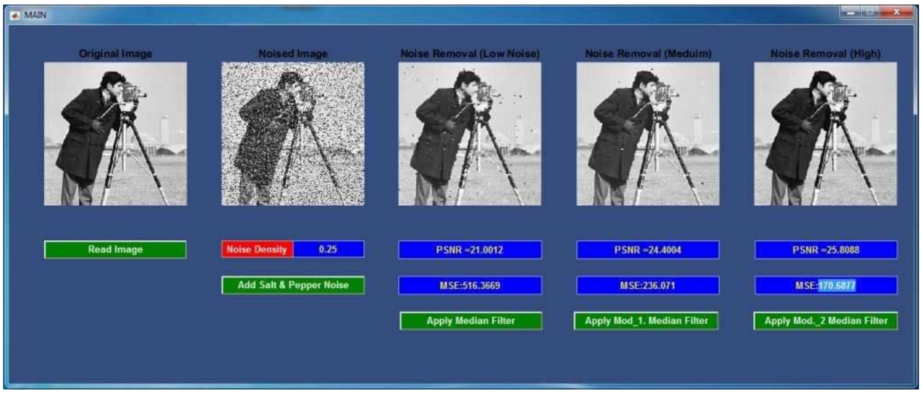
Noise Density 0.05

PSNR =25.3658
MSE:189.0154

PSNR =31.351
MSE:47.6408

PSNR =31.2839
MSE:48.3827

Figure 7: Noise removal for Cameraman with noise Density (0.05) using three methods



Noise Density 0.25

PSNR =21.0012
MSE:516.3669

PSNR =24.4004
MSE:236.071

PSNR =25.8088
MSE:170.6877

Figure 8: Noise removal for Cameraman with noise Density (0.25) using three methods

Noise Density 0.5

PSNR =13.4311
MSE:2951.0254

PSNR =17.025
MSE:1289.9631

PSNR =21.9058
MSE:419.272

Figure 9: Noise removal for Cameraman with noise Density (0.5) using three methods

Noise Density 0.05

PSNR =31.6438
MSE:44.5346

PSNR =34.8176
MSE:21.4446

PSNR =35.2051
MSE:19.6144

Figure 10: Noise removal for Pepper with noise Density (0.05) using three methods

Noise Density 0.25

PSNR =24.7855

MSE:216.038

PSNR =25.9606

MSE:164.8223

PSNR =27.8935

MSE:105.6158

Figure 11: Noise removal for Pepper with noise Density (0.25) using three methods

Noise Density 0.5

PSNR =14.9137

MSE:2097.5423

PSNR =18.3417

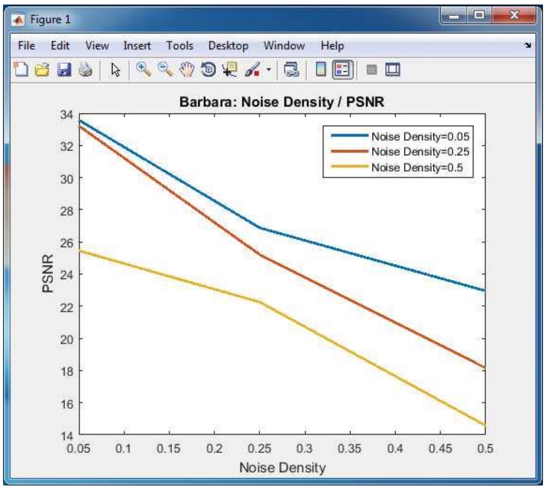
MSE:952.6092

PSNR =24.3351

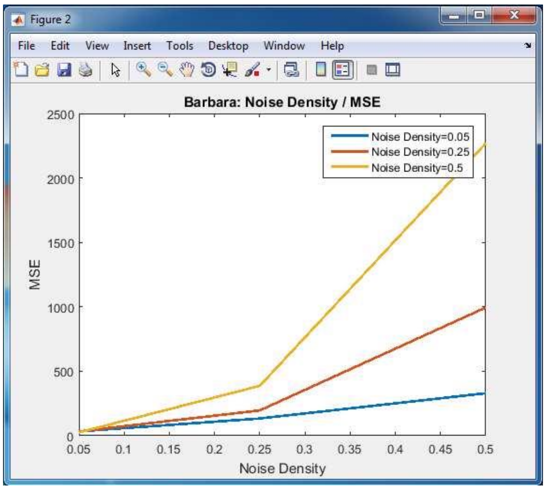
MSE:239.6487

Figure 12: Noise removal for Pepper with noise Density (0.5) using three methods

The figures 13 to 15 show the Comparison of all methods in terms of PSNR and MSE for three above images.

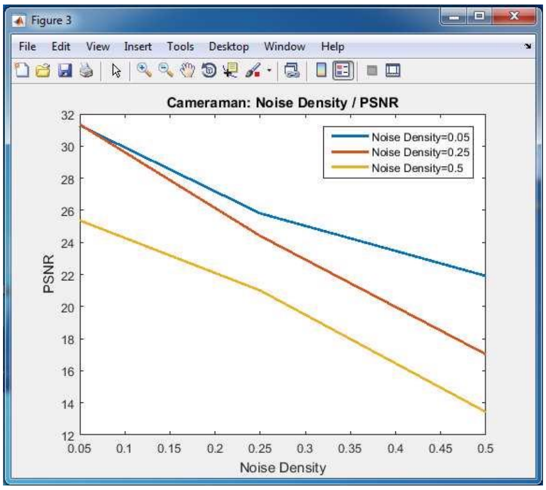


(a)

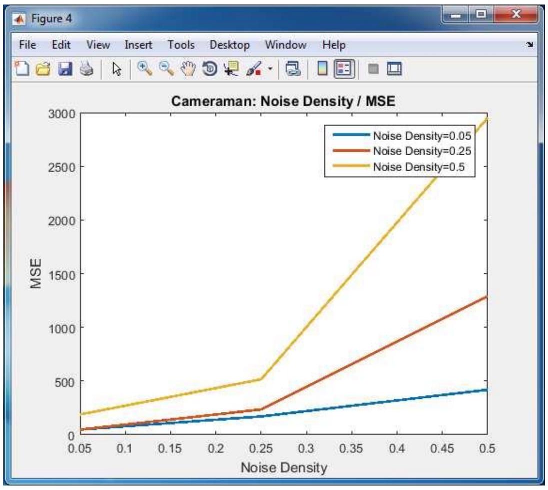


(b)

Figure 13: Comparison of all methods in terms of (a) PSNR and (b) MSE for Barbara

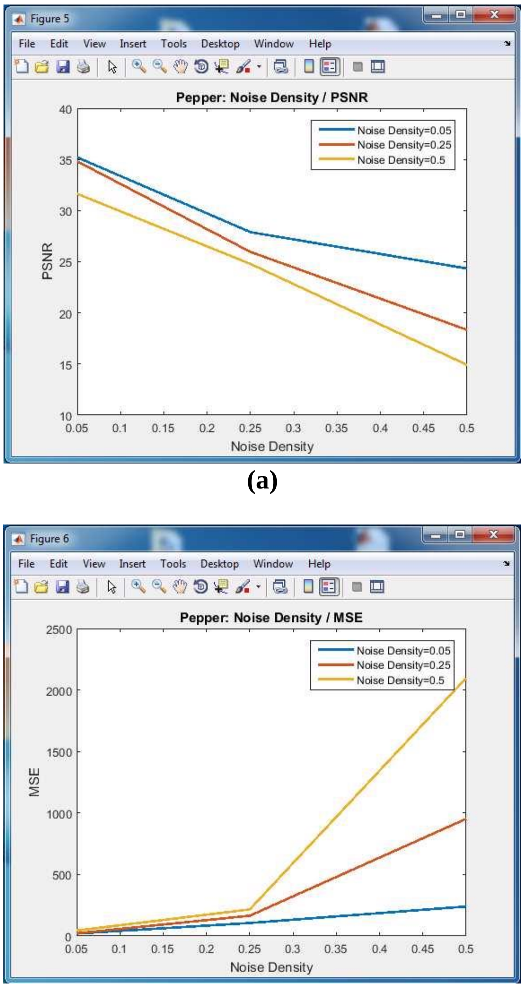


(a)



(b)

Figure 14: Comparison of all methods in terms of (a) PSNR and (b) MSE for Cameraman



(a)

(b)

Figure 15: Comparison of all methods in terms of (a) PSNR and (b) MSE for Pepper

By comparing median and weighted median filters, this research hopes to find out which one is better at minimizing digital photos' salt and pepper noise. Image quality may be severely diminished by this noise, especially when it's present at high levels. Despite its widespread usage, the median filter might struggle in very noisy settings owing to its inability to effectively reduce background noise while retaining edges. A weighted median filter, which gives more weight to pixels with comparable intensity values and hence improves noise reduction performance, is suggested as an improved approach in the research. Compared to conventional median filtering methods, the weighted median filter outperforms them experimentally, especially in high-noise situations, suggesting a more resilient strategy for preserving picture quality in such environments. In light of this, it seems that the weighted median filter is the way to go for tasks that call for efficient noise reduction in highly polluted pictures.

Conclusions and future works

This work has presented a comparative analysis of median and weighted median filters for high noise salt and pepper noise removal in digital images. The results indicate that while the median filter is effective in reducing noise levels, its performance diminishes in scenarios with extremely high noise densities. Conversely, the weighted median filter demonstrates superior noise reduction capabilities, particularly in regions heavily affected by noise contamination. These findings underscore the importance of exploring advanced filtering techniques for robust noise removal in digital images. Moving forward, future research can focus on further enhancing the efficiency and effectiveness of weighted median filtering methods, exploring adaptive approaches to tailor filter parameters to specific noise characteristics, and investigating the application of machine learning techniques for automated noise reduction in diverse imaging applications. Such endeavors hold promise for advancing the state-of-the-art in image processing and enhancing the quality of digital image analysis and interpretation.

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