


# Median Filter Optimization and *Sharpening* Techniques to Improve Digital Image Quality

Riko Prananda Prayugo<sup>\*1</sup>, Lailan Sofinah Harahap<sup>2</sup>

Science and Technology, Computer Science, State Islamic University of North Sumatra, Medan, Indonesia

Article Info	ABSTRACT
<p><b>Keywords:</b> Median filter, sharpening, PSNR, SSIM, image quality, impulsive noise, digital image processing</p>	<p>The quality of digital images often degrade due to noise disturbances, especially impulsive noise such as salt and pepper. The aim of this study is to optimize the use of the median filter as a denoising technique and to combine it with a sharpening method to enhance the sharpness and clarity of image structures. The proposed approach involves applying an adaptive median filter reduce noise while preserving edge details, followed by a convolution kernel based sharpening technique to further emphasize visual features. The performance of the method is evaluated by compare the Peak Signal-to-Noise Ratio (PSNR) and the Structural Similarity Index Measure (SSIM) between the processed images and the original images. The experimental results demonstrated that this combined approach significantly improve both PSNR and SSIM values after filtering and sharpening, indicating that the synergy between median filtering and sharpening effectively restore the visual quality of digital images. These findings can serve as a foundation for the development of adaptive image preprocessing systems to handle impulsive noise.</p>
<p>This is an open access article under the <a href="https://creativecommons.org/licenses/by-nc/4.0/">CC BY-NC</a> license</p> 	<p><b>Corresponding Author:</b> Lailan Sofinah Harahap Science and Technology, Computer Science, State Islamic University of North Sumatra, Medan, Indonesia lailansofinaharahap@gmail.com</p>

## INTRODUCTION

High-quality digital images are becoming increasingly useful in various industries, such as surveillance, healthcare, visual communication, and artificial intelligence, In today's technological era. *Noise interference* that occurs during acquisition, processing, or transmission, very often causes the quality of the resulting image to decrease. Due to impulsive *noise*, especially *salt* and *pepper noise* that appears as random black and white dots in an image is one of the most common and harmful types [1] of *noise*. The clarity of the image structure is significantly reduced due to this interference, and deeper visual analysis becomes more difficult. To overcome this, digital image processing techniques such as *denoising* have been widely developed. One popular and simple approach is the use of a *median filter*. By converting each pixel to the *median value* of a window around it, this *filter* is very useful in removing impulsive *noise* without significantly blurring the image edges [2]. However, *the median filter* has the disadvantage of preserving fine details and complex structures in the image, so further development is needed to optimize the *denoising results* without sacrificing image sharpness.

This study focuses on optimizing the use of *median filters*, which adjust the window size depending on the *noise level* in the local area. This approach is more effective in emphasizing visual details [3]. Then, to improve the overall visual quality of the image, *the median filter* also needs to be combined with sharpening techniques. This technique functions to emphasize the structure and visual features of the image through a sharpening process based on kernel convolution, for example the use of kernels Laplacian or combination of *high-pass methods filtering* [4].

In digital image processing, the quality of the visual appearance of an image is highly dependent on the presence of noise *and* the level of sharpness of the visual features that form it. *Noise* originating from interference from imaging devices or data transmission processes can reduce the accuracy of various advanced analysis processes, such as object separation or segmentation and classification pattern recognition. Therefore, efforts to eliminate *noise* without sacrificing important structures in the image are one of the main challenges. The use of *median filters*, especially the *adaptive type*, has shown very good results in overcoming salt *-and-pepper noise*, while maintaining the integrity of the image object boundaries. However, the resulting images often experience decreased contrast and visual sharpness.

[5]. To overcome this limitation, sharpening techniques *are* applied to clarify significant contours and texture details. By combining *median filters and* kernel *-based sharpening* methods, such as kernel *Laplacian* or *high-pass filter*, is expected to produce images that are not only free from *noise*, but also have optimal visual acuity. This approach is considered suitable for various applications that require image analysis with a high level of accuracy [6].

Several researchers have applied a combined approach between *adaptive filter techniques* and visual quality enhancement to overcome *noise problems* while maintaining the sharpness of image details. One of them is a study by Hidayat Siregar (2024) who evaluated several types of *adaptive filters*, including *adaptive median filters*, in handling various types of image disturbances such as *salt-and-pepper*, Gaussian, and *speckle noise*. They found that *the adaptive median filter* was superior in suppressing *salt-and-pepper noise*, although it requires a relatively higher processing time [7]. On the other hand, research by Fachrunnisa (2023), applies *an adaptive median filter* to medical images using MATLAB for visual quality restoration purposes. The results are quite significant in reducing *noise*, but are not yet equipped with a visual sharpening mechanism such as *sharpening* to clarify the contours and structure of the image [8]. Therefore, this research attempts to design a more efficient and structured solution through the integration of *adaptive median filter-based denoising and image sharpening* with a convolution kernel approach, which is able to maintain fine texture structures and improve image display accuracy for various visual analysis purposes.

In this study, a combined method of *adaptive median filtering and convolution* kernel-based *sharpening* techniques was used. This method aims to eliminate *impulsive noise* effectively while emphasizing the image structure. This process begins with the application of *an adaptive median filter* to reduce *salt and pepper noise*, then continued with the application of the kernel *sharpening* in MATLAB to clarify visual features. Evaluation is done

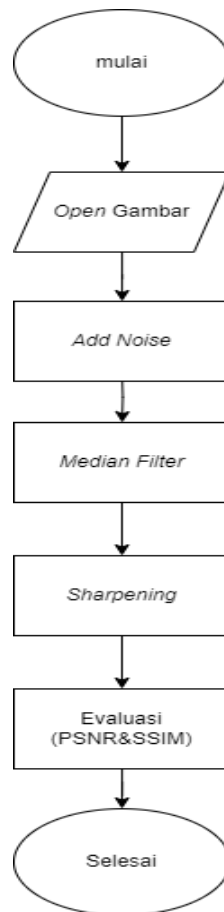
by comparing the results of this combined method to the original image (before being exposed to *noise*) using two objective metrics: PSNR and SSIM [9].

The initial results of this study show that the proposed method successfully improves the PSNR and SSIM values significantly compared to the original noisy image. This indicates that the incorporation of the denoising approach *adaptive median filter* and kernel-based sharpening can efficiently reduce the effect of impulsive *noise*, while maintaining the visual structure and edge details of the image well. This success also emphasizes that the method can be used as a reliable and effective approach for various digital image processing needs, especially in high-precision fields such as medical image processing, surveillance systems, pattern recognition, and other computer vision-related applications. In addition, the developed method can also be easily adapted and implemented, both as software and hardware on a small scale, so it has the potential to be a foundation for the development of a more adaptive image pre-processing system that can be widely applied.[10]

## RESEARCH METHODOLOGY

### Stages Study

This research aims to improve the quality of digital images contaminated by impulsive *noise*, especially *salt. and pepper noise*, through the combined application of the *median method filtering* and *sharpening techniques*. Both of these methods work together. *Median filter* effectively removes *noise. impulsive* without damaging the edge structure of the image, while *sharpening* serves to clarify visual details and strengthen contours that previously decreased due to the *denoising process*. The image dataset used in this study was obtained from the platform Kaggle, which provides various sources of high-quality digital image data. making it suitable for testing image processing methods based on *filtering* and sharpness enhancement. The stages in this study are arranged systematically and structured in order to be able to produce an optimization process that can be evaluated quantitatively using two main metrics, namely PSNR ( *Peak Signal-to-Noise Ratio* ) and SSIM ( *Structural Similarity Index* ).



**Figure 1.** Flow Diagram

In the image above, the stages of the research flow in optimizing the quality of digital images affected by *impulsive noise* with *the filtering and sharpening methods*. The flow begins with the image acquisition process through the *Open Image stage*. After the image is selected and opened, the system automatically adds *noise. salt and pepper* through the *Add process Noise*. Then, the *noisy image* is processed using *the Median Filter* to remove *impulsive noise*, then continued with the *Sharpening stage* to emphasize and increase the sharpness of the structure in the image. After the entire repair process is carried out, the next stage is the evaluation of image quality using two main metrics, namely PSNR ( *Peak Signal-to-Noise Ratio* ) and SSIM ( *Structural Similarity Index* ), which is shown in the Evaluation block (PSNR & SSIM). This process is arranged systematically to provide accurate and relevant results.

### Image Processing

Image processing is the process of processing and analyzing images that involve a lot of visual perception. In this image processing process, it has characteristics in the form of input data and output information in the form of images. However, the image produced from this image processing has better quality. In terms of digital image processing in general, it can be interpreted as two-dimensional image processing with a computer [11].

### **Noise**

*Noise* is a disturbance caused by the storage of digital data received by the image data receiver that can interfere with image quality. *Noise can be caused by physical ( optical )* disturbances on the image capture device, for example, dust dirt that sticks to the photo lens or due to improper processing [12]. Noise is a disturbance or defect in an image that causes the image to become less clear *and* reduces the information contained in it. *Noise* can be in the form of pixels or patterns that interfere and reduce the visual quality of the image. [13].

### **Median Filter**

*Median Filter* is a fairly popular *filter because for some types of random noise it has* excellent *noise* reduction capabilities with the consideration of producing less blurring effect compared to *linear smoothing filters*. *Median filtering* is used to reduce *noise*, especially impulsive *noise*. *Median filtering* works by replacing pixel values with the median value of the surrounding pixels. This method is very effective in removing noise without reducing important details in the image, so it is often used in applications that require high image quality [14]. Median filters are often used to smooth and to restore parts of the image that contain noise in the form of white dots.[15].

### **Sharpening**

*Sharpening* is a technique used to increase the sharpness of an image by highlighting edges and details. Image Sharpening Method sharpening that has been developed is by using the classical method, where data is processed using bits that have a value of 0 or 1. Along with the development of the computational model, a computational model based on quantum principles has now developed. In quantum computing, data is calculated using quantum bits ( *qubits* ), which can process data not only with a value of 0 or 1 but a combination of values 0 and 1. [16]*Sharpening* techniques are also used to reduce *noise*. This process aims to highlight the edges and details in the image. *Sharpening* adds brightness between adjacent pixels to make object boundaries clearer and images appear sharper[17].

### **PSNR**

PSNR is a method commonly used to determine the similarity of processed images to the original image. PSNR is a calculation method to evaluate the value of the resulting image. The PSNR value is obtained by comparing the MSE value in the image. The higher the PSNR value, the better the results obtained.[18].

### **SSIM**

SSIM is a metric that measures the structural similarity between the original image and the stego image based on luminance, contrast, and structure. SSIM ( *Structural Similarity Index Measure* ) is a metric used to measure the level of similarity or structural similarity between two images, namely the original image and the processed image. The SSIM value is on a scale of 0 to 1, where a value closer to 1 indicates that the tested image is very similar to the original image, while a lower value indicates significant changes in the structure or visual quality of the image [19].

### **MATLAB**

MATLAB stands for *Matrix Laboratory* and is a commercial *software by The Mathworks, Inc2*. MATLAB is used for mathematical calculations, data analysis, modeling, simulation,

creating graphs and developing computing. At a glance, MATLAB is a calculator to help calculations in the field of engineering and creating graphs or *plotting* [20].

Testing is done using MATLAB, and the results of each process are visualized in the GUI in MATLAB. PSNR and SSIM values are used to assess the success of the *filtering* and *sharpening processes*.

## RESULTS AND DISCUSSION

### Image Processing

#### Image Acquisition

The images used in this study are color digital images obtained from open datasets available on *the platform*. Kaggle. The dataset was chosen because it presents images with high resolution quality, optimal color balance, and objects that have detailed visual structures. This makes it suitable for testing purposes on image processing methods, especially for the process of filtering *noise* and sharpening images. One of the image samples used in this experiment is an image of a cat which serves as the initial input data. This image acquisition step is carried out via the *Open button* on the graphical user interface (GUI) developed using MATLAB. After the image is successfully uploaded into the system, the image is immediately displayed in the first area ( *Original Image* ) as the initial image data before being given *noise interference*. This stage has a role because the quality of the original image will be used as the main comparison in assessing the effectiveness of the image improvement process, which is evaluated using the PSNR ( *Peak Signal-to-Noise* ) *value. Ratio* ) and SSIM ( *Structural Similarity Index* ) at the final stage of processing.



Figure 2. Original Image

#### Addition of Noise

At this stage, it is done to add interference to the image by inserting *noise. salt and pepper, which is a type of impulsive* noise that randomly adds black and white pixels to the image. This process is done automatically via the *Add button. Noise* in MATLAB GUI. The addition of *noise* causes a drastic decrease in the visual quality of the image, especially in the

fine texture and object outlines. The presence of *noise* makes the image structure unclear and makes it difficult for the system to maintain important details, so this stage is important to test the ability of the filtering method *to* restore image clarity in the next process.

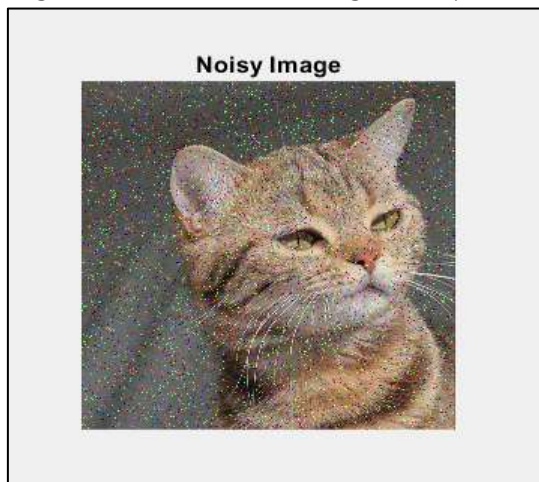


Figure 3. Adding Noise to the Image

### Median Filtering Process

After the image experiences *noise interference*, a *filtering process* is carried out using the *median method. filter*. This filter works effectively to eliminate *impulsive noise* by maintaining the edges of the image. In order for the image quality improvement to be analyzed objectively, the results of the *filtering process* are first converted into *grayscale format* before being measured using the PSNR ( *Peak Signal-to-Noise) metric. Ratio*) and SSIM ( *Structural Similarity Index*). This conversion is done because both metrics are more stable and accurate when applied to single intensity scale images compared to color images (RGB) which have three channels. By using *grayscale images*, the evaluation becomes more focused on the differences in pixel values and *spatial* structures, so that changes in PSNR and SSIM values truly reflect how much quality has improved after the filtering process is carried out.



Figure 4. Results *Median Filtering*

### Sharpening Process

The results of *the filtering* are then enhanced in sharpness quality through *sharpening techniques*. The purpose of this stage is to highlight fine details in the image, especially the edges.

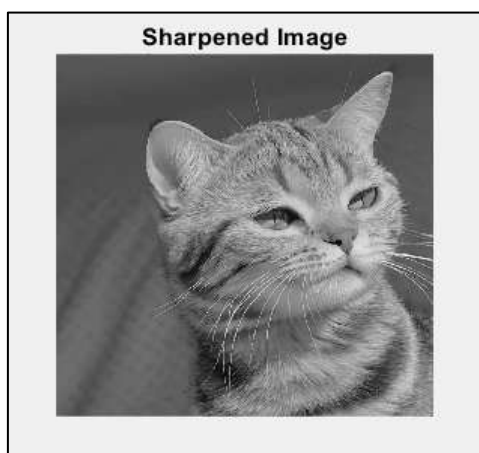


Figure 5. *Sharpening Results*

The results of the *filtering process* are then enhanced by applying the *sharpening technique*. The purpose of this stage is to show fine details in the image, especially the structure of the edges and texture patterns, so that the contours and shapes of the objects can be seen more clearly and firmly. After the *sharpening process* is carried out, the image that was initially free of noise now not only looks clearer, but also sharper and richer in detail.

### Image Quality Evaluation

Quality assessment is carried out using two metrics, namely PSNR ( *Peak Signal-to-Noise Ratio* ) and SSIM ( *Structural Similarity Index* ).

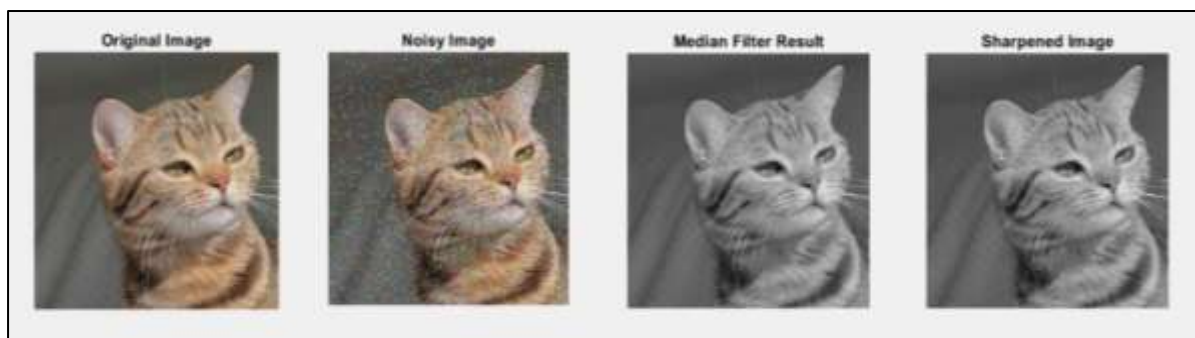


Figure 6. Final Result After Median *Filter* and *Sharpening*

In Figure 6. above shows a comparison of the visual quality levels of a digital image from the beginning until after going through various stages of processing. First, *Original Image*, the original image is shown with complete details and pattern structure, used as a reference before the repair process is carried out. In the second panel, *Noisy Image*, displays an image that has been disturbed by *noise. salt and pepper*, making the image pattern look full of random dots and the structure details become less clear. Next, In the third panel, *Median*

*Filter Result*, shows the results of applying *the median filter* which successfully reduces or dampens the effects of *impulsive noise*, while still maintaining the shape of the edges and object patterns well. And finally, the *Sharpened panel Image*, shows an image that has gone through a sharpening process to emphasize edges and structural details, resulting in a clearer visualization that approaches the quality of the original image. Overall, this sequence of images represents the steps of image quality improvement from the initial noisy condition to the final stage with clearer and sharper structure and details.

**Table 1.** Improvement of PSNR and SSIM at different values image

Stages	PSNR (dB)	SSIM
Original Image	$\infty$	1.0000
<i>Noise</i>	22.07	0.3808
<i>After Filtering</i>	32.49	0.9217
<i>After Sharpening</i>	31.70	0.9193

Table 1 shows the image quality values of -each processing stage with PSNR and SSIM parameters. In the initial image, the PSNR value is at infinity and SSIM is 1.0000, which indicates that the image quality and structure are in perfect condition without any changes. After adding *noise*, the PSNR value drops drastically to 22.07 dB, and the SSIM value also drops drastically to 0.3808, indicating a high level of damage. After *median filtering*, the PSNR value increases significantly again to 32.49 dB and SSIM also recovers to 0.9217, while after sharpening, the PSNR value decreases slightly to 31.70 dB and the SSIM value is at 0.9193, indicating that the visual quality and structure of the image pattern can still be maintained very well.

### Discussion

Based on the data above, the results of this study can be concluded that the application of *median filters* and *sharpening* very efficient and very good at reducing *noise interference salt and pepper* and sharpen the image quality results, as seen from the change in value of the original image. Then the PSNR value increased significantly from 22.07 dB (when given *noise* ) to 32.49 dB after the *Median filtering process*, and the SSIM value also increased drastically from 0.3808 to 0.9217, which indicates that the structure and visual details of the image can be maintained very well. Furthermore, the application of the *sharpening method* also provides a positive contribution with a PSNR value of 31.70 dB and SSIM of 0.9193, which although slightly lower than the *filtering stage*, remains at a high value and proves that edge details and structural patterns can be superior without sacrificing visual quality significantly. but also emphasizes the edges and visual details so that image quality remains optimal. This study confirms that *the median filter* is very good at overcoming *impulsive noise*, and when combined with the *sharpening technique*, it can produce images with a much better level of sharpness, clarity, and visual quality, so that it can be used as an effective method in image processing with high levels of interference

## CONCLUSION

The median filter and sharpening methods has proven to be very effective in improving the quality of images exposed to *noise. salt and pepper*. The PSNR value was initially at 22.07 dB for the contaminated image. *noise*, successfully increased significantly to 32.49 dB after the filtering process with the median method, while the SSIM value also increased from 0.3808 to 0.9217, which indicates that the structure and visual details of the image can be restored very well. Furthermore, the application of the sharpening method also gave positive results, with a PSNR value of 31.70 dB and an SSIM value of 0.9193, which although slightly lower than the filtering stage, remains at a high level and proves that this method can emphasize edge patterns and structural details without reducing image quality. These results emphasize that the combination of median filter and sharpening can be a reliable approach for image processing with high levels of noise, especially in restoring details of visual patterns and structures. However, this study also has shortcomings, namely that it has not explored various other types of noise or advanced methods such as wavelets or deep learning, which can provide a more comprehensive picture of the method's adaptability. Therefore, further development is also needed to expand the capabilities and usability of the image processing system, so that it can be applied more adaptively and efficiently in various visual disturbance scenarios.

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