Research Article

Image quality enhancement by applying a combination of filtering between the median filter and CLAHE

[1]Adinda Tarisyah Hsb, [2,*]Lailan Sofinah Harahap, [3]Hasti Fadillah

[1,2,3] Department of Computer Science, Universitas Islam Negeri Sumatera Utara, Indonesia

* Corresponding Author: lailansofinahharahap@gmail.com

Abstract: Digital image quality is often degraded due to disturbances such as salt-and-pepper noise and uneven lighting. This can hinder further image analysis and processing. This research aims to improve image quality by applying a combination of two filtering methods, namely Median Filter and CLAHE (Contrast Limited Adaptive Histogram Equalization), using MATLAB. Median Filter is used to remove impulsive noise without obscuring important details, while CLAHE is applied to improve image contrast adaptively and locally. Tests were conducted on grayscale images with artificial noise added. The experimental results show that the combination of both methods provides a significant improvement in image quality compared to the use of either method alone. Thus, this approach is effectively used for image pre-processing that requires detail recovery and contrast enhancement.

Keywords: Image Processing, Median Filter, CLAHE, noise, pepper-salt

Citation: Adinda Tarisyah Hsb, Lailan Sofinah Harahap, & Hasti Fadillah. (2025). Image quality enhancement by applying a combination of filtering between the median filter and CLAHE. *Iota*, 5(2). https://doi.org/10.31763/iota.v5i2.921

Academic Editor: Adi, P.D.P

Received: April 09, 2025

Accepted: April 21, 2025

Published: May 15, 2025

1. Introduction

Digital images are 2-dimensional data that have color intensity information. The advantage of digital image data over other data is its ability to detect and recognize objects in a non-contact, non-destructive, remote, and wide-view manner. The implementation of digital images, among others, is used as an analysis of industrial products, agricultural products, medical conditions, traffic conditions, and environmental conditions in remote sensing images. The discussion on digital image processing consists of 3 basic components, namely color conversion, segmentation, and filters [1].

However, in the process of taking or transmitting images, there is often interference in the form of noise or a decrease in contrast that can affect the quality of the image. One type of noise that often appears is salt and pepper noise, in the form of black and white bits that appear randomly. To overcome this problem, various image processing techniques have been developed [2,3,4]. One commonly used approach is filtering techniques. The use of one method in image processing, for example using only a median filter, is often ineffective in removing the noise. Improving image quality also requires optimizing image contrast. Therefore, this research combines two filtering techniques, namely the median filter and CLAHE methods, so that noise can be removed image details become sharper and the contrast is more even.

The median filter is effective in removing noise by replacing the corrupted pixel value with the median value around it. Meanwhile, CLAHE is a method to improve the local contrast of the image by dividing the image into small blocks and applying histogram equalization adaptively [6,7,8]. By combining the median filter and CLAHE, this research is expected to provide a better solution than the single method, especially in improving the quality of digital images that have problems in this regard [9,10,11].

2. Literature Review

Basically, images can be grouped into 2 parts, namely visible images and invisible images. Various examples of visible images include family photos, wedding photos, tourism photos, wall paintings, images that can be seen on television or computer monitors, and holograms. Meanwhile, invisible images are images that are represented with numerical values or numbers, image data in the form of files on computers, and so on [2]. Image processing is a method used to transform, analyze, and improve digital images following certain objectives. The digital image itself is a visual display composed of a collection of pixels in the form of a two-dimensional matrix, where each pixel contains an intensity value that describes color or gray-level information. Image quality improvement techniques can be used to reduce noise, increase contrast, sharpen details, or improve lighting [3].

In general, images that need improvement are caused by noise in the form of salt and pepper noise. Salt and pepper noise is a type of impulsive noise that appears sporadically at several pixels in an image. This noise is usually caused by obstructing objects such as dust during image capture, errors in the analog-to-digital conversion (ADC) process, or damage to the camera sensor pixels. Noise with high intensity is known as salt noise which appears as bright spots, while noise with low intensity is called pepper noise which appears as dark spots in the image [1]. Moreover, to remove the noise, there are several methods, one of which is the widely used median filter. The median filter is a more effective method for dealing with salt-and-pepper noise. It replaces the value of each pixel with the median value of its neighbors, which helps remove the noise without blurring the edges too much. Median filters are very useful in applications where edge details are very important, such as in medical image processing or video surveillance (Hidayat & Isnanto, 2024).

In addition to removing noise, image contrast enhancement is also an important aspect of image processing, especially in images that have uneven lighting. In this problem, the CLAHE technique can be used. CLAHE is an advanced version of the histogram equalization technique designed to adaptively improve image contrast and detail [12,13,14,15]. This method introduces a limit to the contrast enhancement process, thus preventing excessive noise and keeping image quality stable [5]. Recent research has shown that the combination of Median Filter and CLAHE can result in significant image quality improvement. The Median Filter is first used to remove salt-and-pepper noise, and then CLAHE is applied to locally enhance the contrast so that the details and important features of the image are preserved [16,17,18,19,20].

3. Method

This research uses a combination of median filter and CLAHE (Contrast Limited Adaptive Histogram Equalization) methods. This process begins with a pre-processing stage in the form of image reading and conversion, followed by the application of a median filter to reduce salt and pepper-type noise, which is then followed by the CLAHE process to increase the local contrast of the image. The implementation process is carried out using MATLAB software as a programming tool and visualization of results.

3.1 Median Filter

The working principle of the median filter is to replace the disturbed pixel value with the center value of the surrounding pixels in a certain window. For example, in a 3x3 window, the intensity values of nine pixels are collected, and sorted, and then the median value is selected instead of the center pixel. The main advantage of the median filter is its ability to remove noise without blurring edges or important details in the image, which is often the drawback of linear filters. Therefore, this method is often applied to image enhancement processes that require the preservation of visual details [4].

3.2 CLAHE (Contrast Limited Adaptive Histogram Equalization)

The CLAHE (Contrast Limited Adaptive Histogram Equalization) method is an image quality enhancement technique that works by improving the contrast locally in each part of the image. The process begins by dividing the image into small overlapping blocks, where each block is processed independently. For each block, a pixel intensity histogram is created to capture the local brightness distribution. Next, the histogram is processed through a histogram equalization process so that the intensity values are distributed more evenly so that the local contrast can be enhanced effectively. However, so that the contrast enhancement is not excessive, a clipping limit is applied to prevent extreme histogram values that may amplify noise.

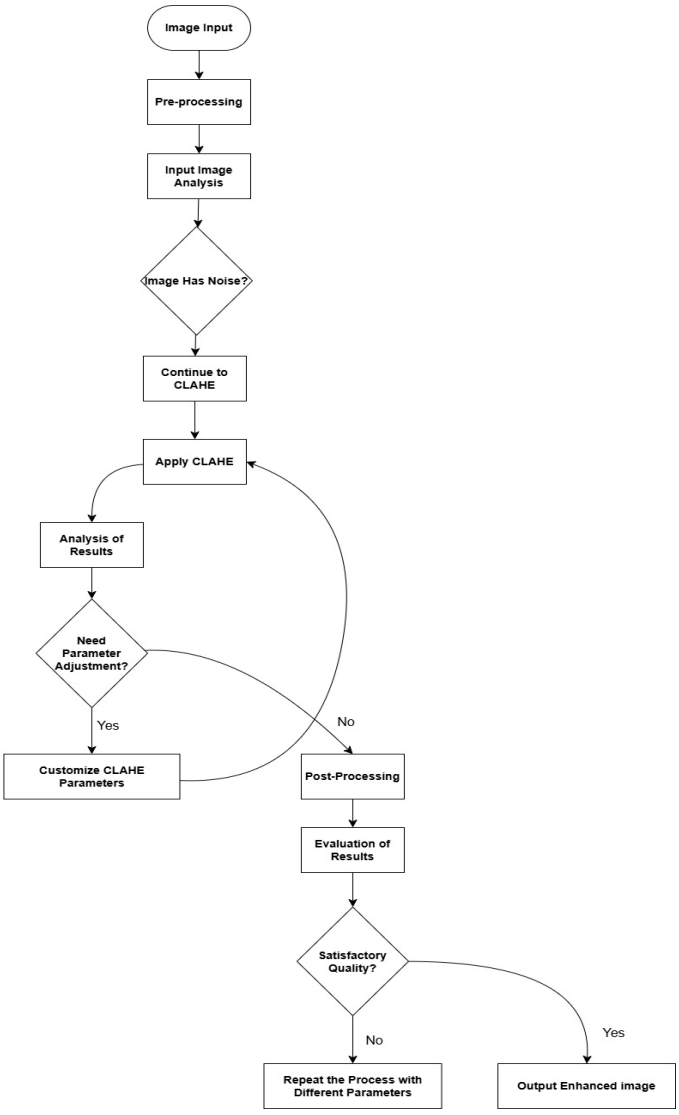

Figure 1. Flowchart of how the method works

After that, interpolation between blocks is performed to ensure smooth transitions between regions and avoid the appearance of unwanted boundary lines. Since CLAHE has the potential to amplify noise already present in the image, additional techniques such as median filter are usually used to reduce the effect. In the final stage, the contrast enhancement results are evaluated both visually and quantitatively to ensure that no

distracting distortions or artifacts occur. With this approach, CLAHE has proven to be very useful in enhancing local details and contrast, especially in images with uneven intensity variations [5].

```
CLAHE Algorithm:
1. Input: Original image I(x,y)
2. Noise Reduction: I1 = MedianFilter(I, kernel_size)
3. Contrast Enhancement: I2 = CLAHE(I1, clip_limit,
tile_size)
4. Output: Enhanced image I2
```

4. Result and Discussion

In this study, the test image used experienced disturbances such as salt and pepper noise and uneven lighting. The processing process is done with three approaches, including: (1) Using only the median filter, (2) Only using CLAHE, and (3) Combination of median filter and CHALE 4.

Figure 2. Citra dengan noise

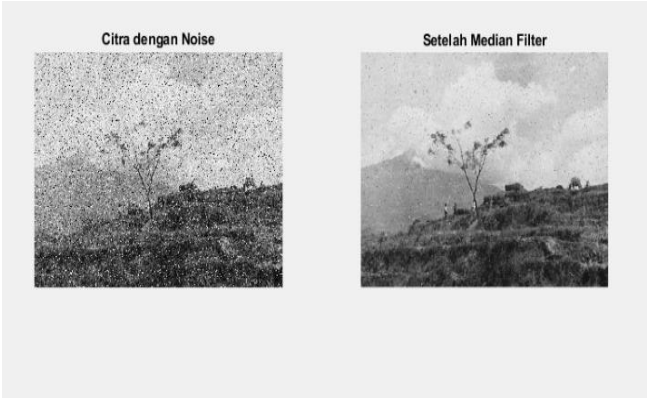

Figure 3. Image result after median filter

The image shows the comparison results of the image before and after processing using the Median Filter. The left image shows salt & pepper type noise characterized by black and white spots that interfere with the appearance of the image. After applying the Median Filter (right image), the noise has been significantly reduced, so that objects such as trees and houses can be seen more clearly. This filter is effective at removing impulsive noise without destroying the main structure of the image, although it does cause a slight smoothing of fine details.

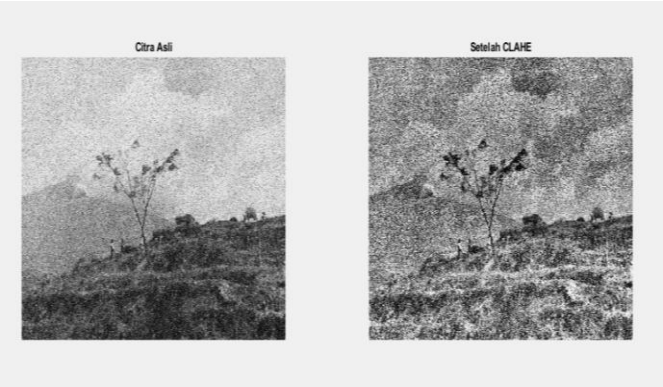

Figure 4. Image result after CLAHE

The image compares the original noisy image (left) with the result after processing using CLAHE (right). CLAHE succeeds in enhancing the contrast of the image, so objects such as trees and landscapes are more clearly visible. However, since the noise has not been removed, the CLAHE effect emphasizes the noise, making the image appear more "noisy". This suggests that CLAHE should be applied after the denoising process for more optimal results.

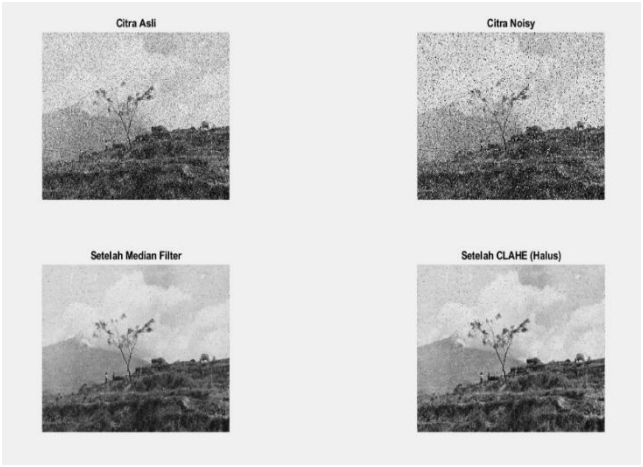

Figure 5. Image result after combination

This image shows the stages of image processing from the original state to the final result. The original image (top left) is then added with salt & pepper noise (top right), which makes it appear full of spots. After that, the noise is reduced using the Median Filter (bottom left), resulting in a cleaner image. Finally, the contrast of the image is enhanced using CLAHE with a fine setting (bottom right), so that details are seen more clearly without adding noise. This combination is effective for cleaning up noise while sharpening the image. Furthermore, from a more comprehensive analysis, the following Enhancement Summary was obtained: Details of Image Enhancement Process Stages can be seen in Figure 6. A more detailed analysis can be seen in Figure 7. Histogram Analysis of Processing Stages, Figure 8 Comprehensive Quality Metrics Analysis, and Figure 9 Parameter Optimization Analysis: Final PSNR: 23.03 dB, Final SSIM: 0.508, Contrast: 62.8 → 57.3, Entropy: 7.43 → 7.33 bits, and Edge Strength: 83.1 → 38.3.

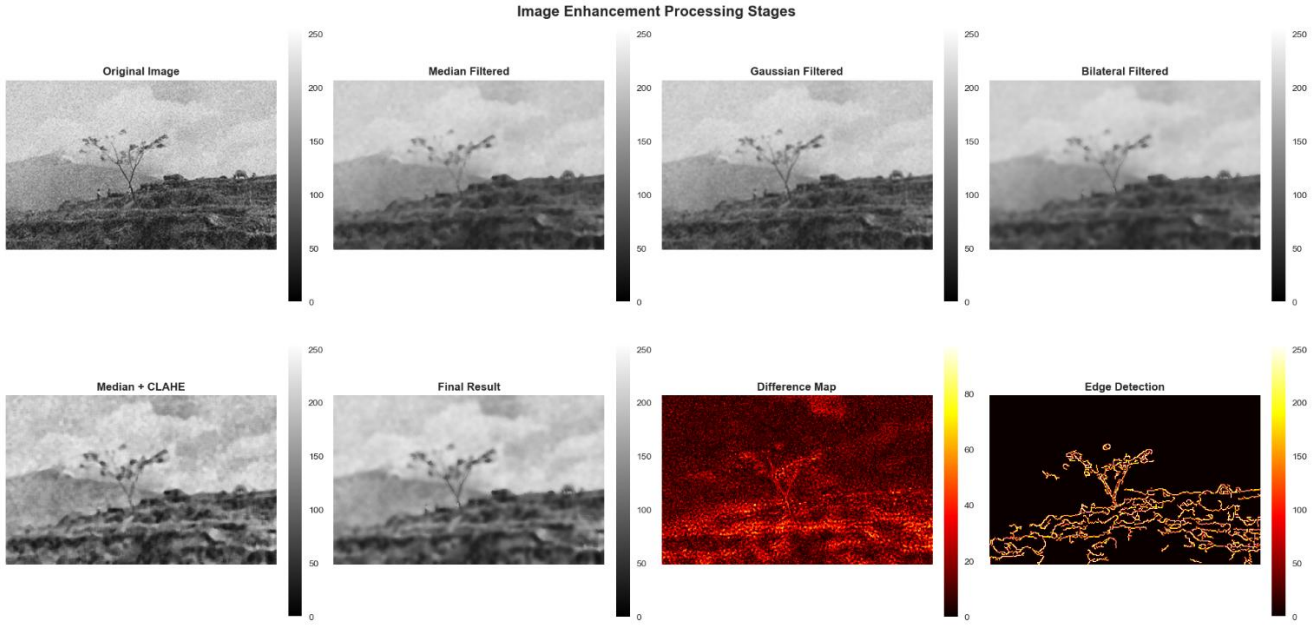

Figure 6. Image Enhancement Process Stages

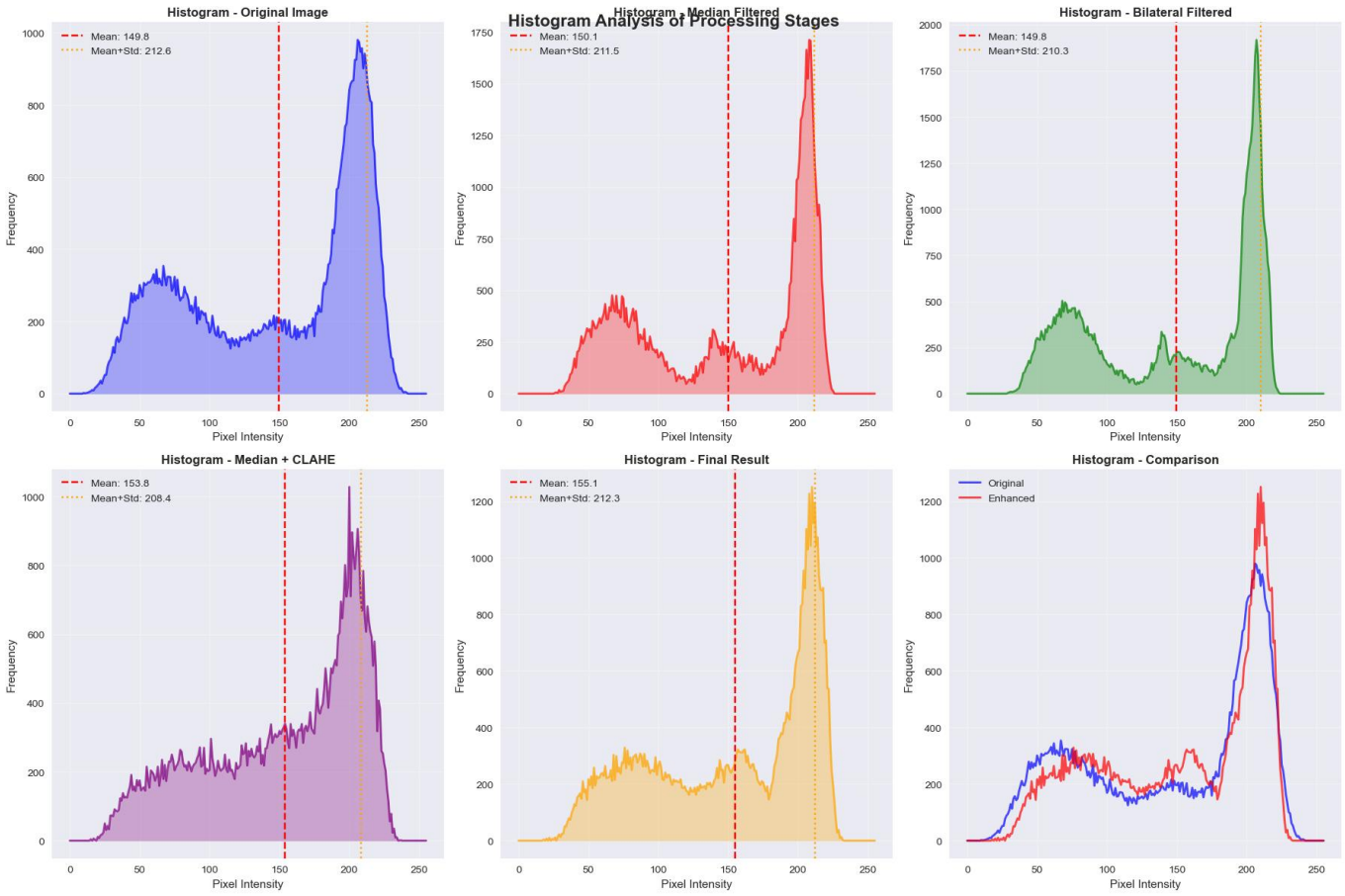

Figure 7. Histogram Analysis of Processing Stages

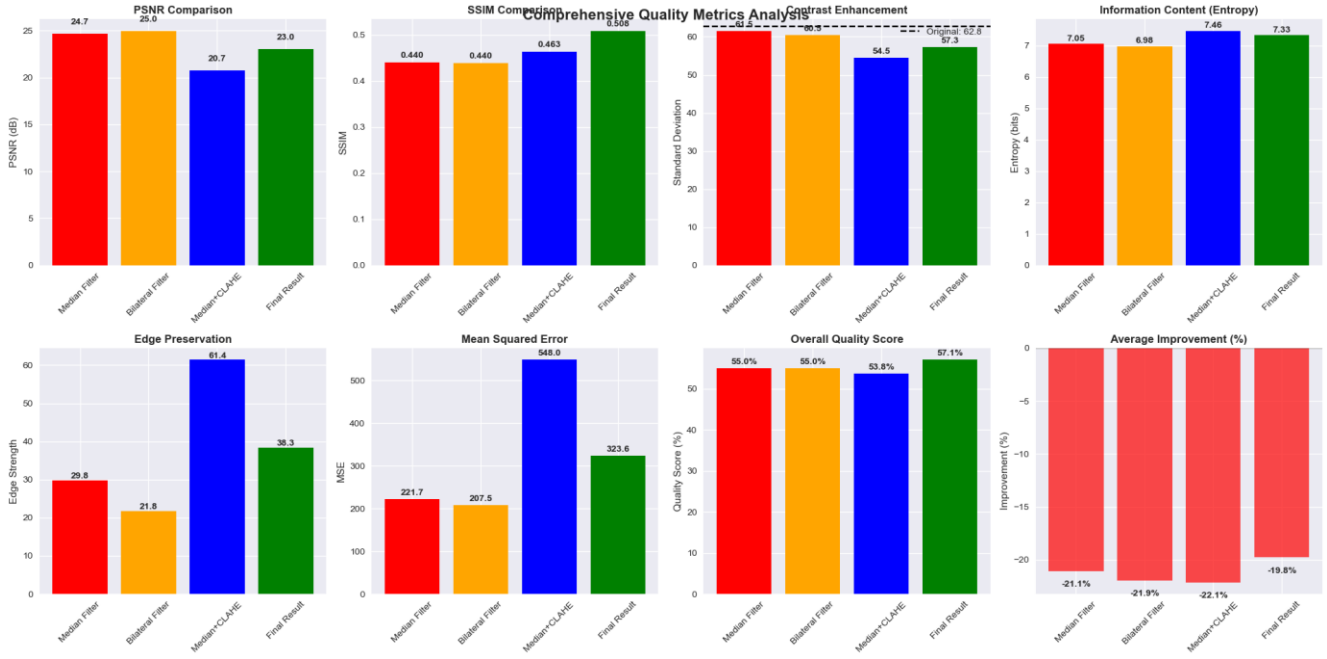

Figure 8. Comprehensive Quality Metrics Analysis

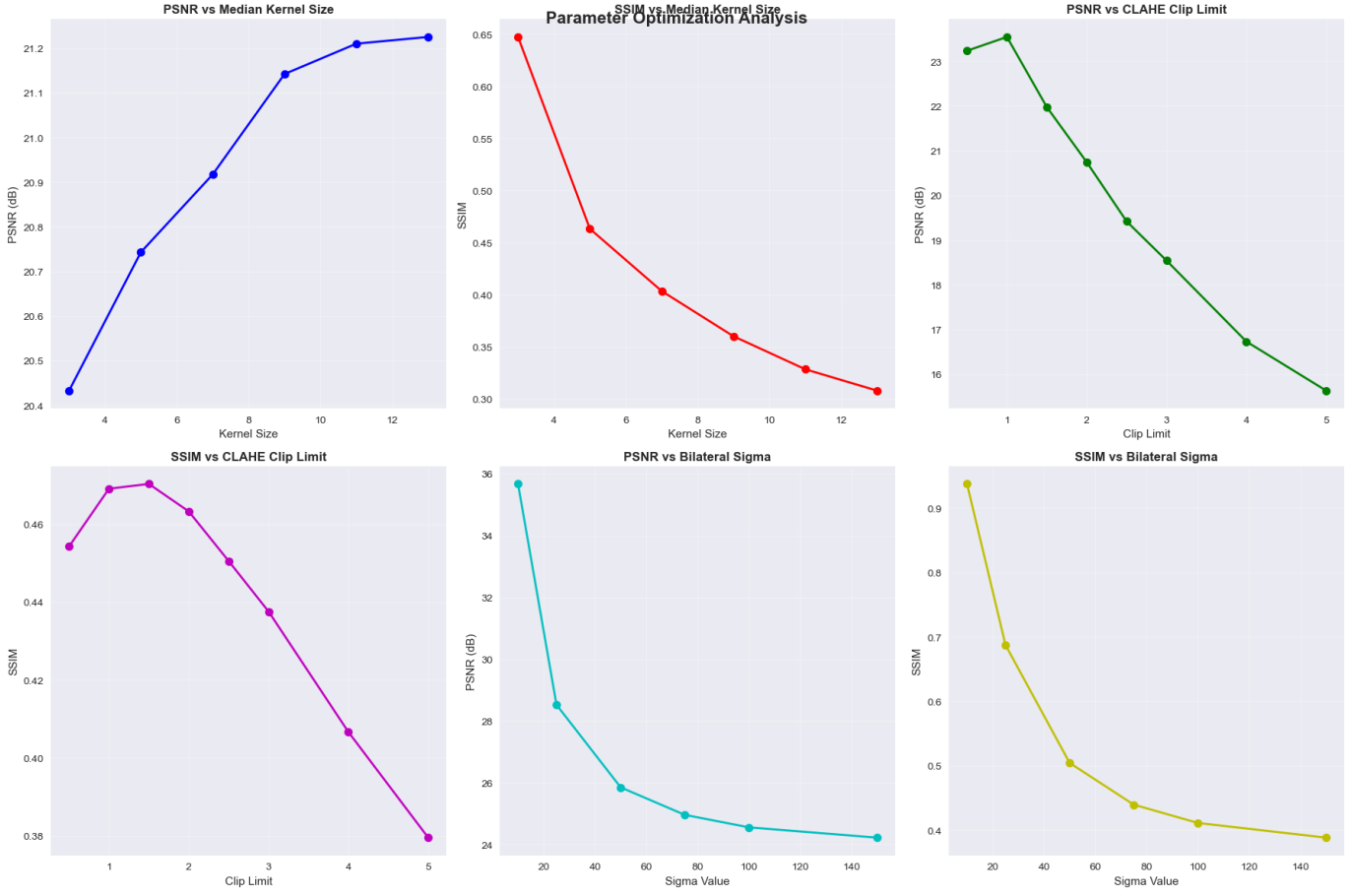

Figure 9. Parameter Optimization Analysis

5. Conclusion

The image processing process, which starts with noise removal using a Median Filter, followed by contrast enhancement using CLAHE, is able to produce images with better visual quality. Median Filter effectively reduces noise, while CLAHE clarifies image details evenly. This approach shows that combining the two techniques can significantly improve image clarity and readability. Median Filter and CLAHE can be proven to provide image quality improvement by overcoming significant noise and contrast issues, this approach excels in detail preservation, local adaptation, and robustness for various image types. An optimized implementation will improve the understanding of the characteristics and tuning parameters. Technological development and computational power.

Acknowledgments: Thanks to all colleagues, peers, and lecturers at the Department of Computer Science, State Islamic University of North Sumatra, Indonesia, hopefully this article will be cited by the same disciplines and be able to increase the novelty in the field of image processing in the future. The author would like to thank the colleagues who have helped in completing this journal. It is hoped that this journal can be useful for readers to increase their knowledge.

Author contributions: The authors are responsible for building Conceptualization, Methodology, analysis, investigation, data curation, writing—original draft preparation, writing—review and editing, visualization, supervision of project administration, funding acquisition, and have read and agreed to the published version of the manuscript.

Funding: The study was conducted without any financial support from external sources.

Availability of data and Materials: All data are available from the authors.

Conflicts of Interest: The authors declare no conflict of interest.

Additional Information: No Additional Information from the authors.

References

[1] H. Fitriyah and R. C. Wihandika, Dasar-Dasar Pengolahan Citra Digital. Malang: Universitas Brawijaya Press, 2021. [Online]. Available: https://books.google.co.id/books?id=LoNTEAAAQBAJ

[2] S. T. M. T. Dr. Ir. Silvester Tena and S. T. M. T. Wenefrida Tulit Ina, Pengolahan Citra Digital. Jawa Tengah: Penerbit CV. SARNU UNTUNG, 2024. [Online]. Available: https://books.google.co.id/books?id=EO0CEQAAQBAJ

[3] S. K. M. K. Mustakim et al., Pengolahan Citra Digital. Batam: Cendikia Mulia Mandiri, 2025. [Online]. Available: https://books.google.co.id/books?id=s0pLEQAAQBAJ

[4] N. Hidayat and R. Isnanto, Pengolahan Citra Digital. Jawa Tengah: Zahira Media Publisher, 2024. [Online]. Available: https://books.google.co.id/books?id=JqhOEQAAQBAJ

[5] I. Yuadi, Forensik Digital dan Analisis Citra. Jawa Timur: CV. AE Media Grafika, 2023. [Online]. Available: https://books.google.co.id/books?id=lXfrEAAAQBAJ

[6] A. Wanto, Y. Yuhandri and O. Okfalisa, "Optimization Accuracy of CNN Model by Utilizing CLAHE Parameters in Image Classification Problems," 2023 International Conference on Networking, Electrical Engineering, Computer Science, and Technology (IConNECT), Bandar Lampung, Indonesia, 2023, pp. 253-258, doi: 10.1109/IConNECT56593.2023.10327100.

[7] N. A. Amalia, A. Afira, M. Ulfa and K. Muchtar, "Utilizing Edge Device and Streamlit for Comparative Evaluation of CLAHE-Based Underwater Image Enhancement Techniques," 2024 IEEE 13th Global Conference on Consumer Electronics (GCCE), Kitakyushu, Japan, 2024, pp. 599-600, doi: 10.1109/GCCE62371.2024.10760315.

[8] E. Ranolo, A. Sebial, A. Ilano and A. C. Canillo, "Seagrass Blurred Image Enhancement and Detection using YOLO and CLAHE Algorithms Performance Comparison," 2023 International Conference on Evolutionary Algorithms and Soft Computing Techniques (EASCT), Bengaluru, India, 2023, pp. 1-5, doi: 10.1109/EASCT59475.2023.10393080.

[9] Z. Yuan et al., "CLAHE-Based Low-Light Image Enhancement for Robust Object Detection in Overhead Power Transmission System," in IEEE Transactions on Power Delivery, vol. 38, no. 3, pp. 2240-2243, June 2023, doi: 10.1109/TPWRD.2023.3269206.

[10] W. Lu, Q. Sun and A. Li, "Improved CLAHE Algorithm Based on Independent Component Analysis," 2024 3rd International Conference on Electronics and Information Technology (EIT), Chengdu, China, 2024, pp. 920-923, doi:

10.1109/EIT63098.2024.10762100.

[11] E. D. Putra, E. Ermatita and A. Abdiansyah, "The Model Regularized CLAHE-CNN for the Traditional Script Character of Kaganga Bengkulu Recognition," 2024 Ninth International Conference on Informatics and Computing (ICIC), Medan, Indonesia, 2024, pp. 1-5, doi: 10.1109/ICIC64337.2024.10957182.

[12] D. G. Serrano-Díaz, W. Gómez, A. Vera and L. Leija, "Contrast Enhancement of 3D X-ray Microtomography Using CLAHE for Trabecular Bone Segmentation," 2023 Global Medical Engineering Physics Exchanges/Pacific Health Care Engineering (GMEPE/PAHCE), Songdo, Korea, Republic of, 2023, pp. 1-6, doi: 10.1109/GMEPE/PAHCE58559.2023.10226484.

[13] R. Sharma and A. Kamra, "A Review on CLAHE Based Enhancement Techniques," 2023 6th International Conference on Contemporary Computing and Informatics (IC3I), Gautam Buddha Nagar, India, 2023, pp. 321-325, doi: 10.1109/IC3I59117.2023.10397722

[14] T. R. Noviandy, A. Maulana, F. Khowarizmi and K. Muchtar, "Effect of CLAHE-based Enhancement on Bean Leaf Disease Classification through Explainable AI," 2023 IEEE 12th Global Conference on Consumer Electronics (GCCE), Nara, Japan, 2023, pp. 515-516, doi: 10.1109/GCCE59613.2023.10315394.

[15] R. Shah, A. Sheikh, S. Shukla, A. Hingmire and O. Suryavanshi, "Comparing Effectiveness of GAN and CLAHE for Enhancing Underwater Images," 2023 7th International Conference on Trends in Electronics and Informatics (ICOEI), Tirunelveli, India, 2023, pp. 1499-1503, doi: 10.1109/ICOEI56765.2023.10125992.

[16] G. W. Intyanto, R. Apriyanto, K. Anam, A. R. Chaidir, C. S. Sarwono and A. C. Eska, "UGER: Enhancing the Quality of ROUV Image Segmentation with CLAHE and Color Space-Morphology Masking Techniques," 2024 IEEE 2nd International Conference on Electrical Engineering, Computer and Information Technology (ICEECIT), Jember, Indonesia, 2024, pp. 1-5, doi: 10.1109/ICEECIT63698.2024.10859578.

[17] K.Halloum & H.Ez-Zahraouy. 2025. Enhancing Medical Image Classification through Transfer Learning and CLAHE Optimization. Current Medical Imaging. Volume 21, 2025. doi. 10.2174/0115734056342623241119061744

[18] Kaur., Navneet. 2025. Hybrid image splicing detection: Integrating CLAHE, improved CNN, and SVM for digital image forensics. Expert Systems with Applications. Volume 273, 10 May 2025, 126756. doi. 10.1016/j.eswa.2025.126756

[19] Rangaiah., P.K.B. 2025. Improving burn diagnosis in medical image retrieval from grafting burn samples using B-coefficients and the CLAHE algorithm. Biomedical Signal Processing and Control. Volume 99, January 2025, 106814. doi. 10.1016/j.bspc.2024.106814

[20] P.K.B. Rangaiah., et.al. 2025. Histopathology-driven prostate cancer identification: A VBIR approach with CLAHE and GLCM insights. Computers in Biology and Medicine. Volume 182, November 2024, 109213. doi. 10.1016/j.compbiomed.2024.109213