

Parameter Optimization of CLAHE Method and Unsharp Mask Filter for Historic Image Quality Improvement

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ABSTRACT

Historical images, such as old documentary photographs, ancient maps, manuscripts, or printed archives, are an important part of cultural and scientific heritage that provide a visual record of the past. Many available historical images have poor image quality because camera technology at that time was still in its infancy. This study examines the optimization of the combination of CLAHE (Contrast Limited Adaptive Histogram Equalization) and Unsharp Masking to improve the quality of historical images that have poor contrast, noise, and faded details. The approach includes preprocessing (greyscale image), CLAHE parameter optimization (clip limit) with a range of 0.01, 0.02, 0.03, 0.04, 0.05, and the Unsharp Mask method with a radius parameter of 1 and an amount parameter of 0.8. The clip limit parameter will be found that has better performance. To evaluate performance, the objective metrics Mean Squared Error (MSE) and Peak Signal-to-Noise Ratio (PSNR) are used. Based on the criteria of the smallest MSE and the highest PSNR, the results showed that a clip limit of 0.01 was the most optimal parameter. This configuration proved effective in increasing contrast, sharpening detail, and minimizing noise, thus improving the quality of historical image restoration.

Keywords: CLAHE; clip limit; unsharp mask.

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1. INTRODUCTION

Historical images, such as vintage documentary photographs, ancient maps, manuscripts, or printed archives, are important media for recording past events, knowledge, and culture. These images not only have aesthetic value but also serve as crucial sources of information for historical, archaeological, geographical, and cultural studies research. However, the physical condition and visual quality of historical images often deteriorate over time. Many major events from the past were fortunate enough to be captured by cameras, but due to technological limitations at the time, the resulting images were unclear or incomprehensible (Fatimatussahro, 2021).

Some factors that contribute to the degradation of historical image quality include limitations in photographic technology in the past, suboptimal storage, imprecise printing processes, and physical damage to media such as paper or film. Common problems include low contrast, blurring, high noise, and uneven lighting. These conditions make it difficult to observe important details, either manually by researchers or automatically using optical character recognition (OCR) technology or computer-based image processing (Widihasaniputri, 2025).

In the context of digital preservation, image enhancement is a crucial step before archival images are further used (Banham 1997). One widely used method is Contrast Limited Adaptive Histogram Equalization (CLAHE), which can adaptively increase contrast in local areas of an image without producing a significant increase in noise. However, applying CLAHE alone is not sufficient to highlight fine details such as thin lines, texture patterns, or faint object edges.

To overcome these limitations, the Unsharp Masking method can be used as a complement. Unsharp Masking works by enhancing the detailed components of an image through edge enhancement, thus making the lines and shapes of objects clearer (Zerbino, 2019; Alsaygh, 2022). The combination of

CLAHE for contrast enhancement and Unsharp Masking for detail enhancement is expected to produce historical images with better visual quality, both in terms of contrast, sharpness, and structural clarity.

Parameter optimization in both methods is crucial because different parameter values will result in varying degrees of quality improvement. Objective image quality evaluation using Mean Squared Error (MSE) and Peak Signal-to-Noise Ratio (PSNR) can help determine the optimal parameter configuration. Therefore, this research not only aims to improve the visual quality of historical imagery but also supports cultural heritage preservation efforts and facilitates visual data analysis in scientific studies.

2. RESEARCH METHOD

The data used in this study consists of a collection of historical images obtained from various online sources. The historical images used generally have low visual quality, with most being in monochrome or grayscale format. For images that are still in color, a grayscale conversion process is performed as an initial stage (preprocessing) to simplify the color composition and focus on the distribution of pixel intensity. In digital images, the degree of grayscale is highly dependent on the number of bits used to represent the gray values in the image (Munir, 2019).

The preprocessing stage aims to prepare the image for processing in the image enhancement stage. The image quality improvement process in this study applies a combination of the Contrast Limited Adaptive Histogram Equalization (CLAHE) method to increase local contrast and Unsharp Masking as a sharpening filter to clarify edge and texture details. CLAHE is an image processing technique to improve image quality. The CLAHE method is an improvement of the previous method, AHE (Adaptive Histogram Equalization) (Rai, 2012; Hidayat, 2025). The Unsharp Masking process is a very effective way to increase sharpness and smooth images, especially for scanned images that sometimes lack sharpness (Sari, 2018). However, this process can produce disturbing and undesirable effects. The effect produced by oversharpening is called the halo effect (Nugraha, 2016; Rajagukguk, 2022; Pham, 2022).

Optimization was carried out on the main parameters of the two methods, namely:

1. CLAHE → The clip limit parameter value is applied to limit excessive contrast amplification, so that noise is not significantly amplified. In this study, optimization was performed on the clip limit parameter with tested values of 0.01, 0.02, 0.03, 0.04, and 0.05. This value variation aims to find the optimal clipping limit that provides the best balance between contrast enhancement and preventing noise amplification.
2. Unsharp Masking → *In this study, the radius parameter (which determines how large an area will be blurred) was set to 1, and the amount parameter (which controls how much sharp detail is added back) was set to 0.8. These settings were chosen to achieve a significant sharpening effect without introducing excessive artifacts.*

Image quality evaluation is performed objectively using two full-reference quantitative metrics:

- Mean Squared Error (MSE) → Measures the mean squared difference in pixel intensity between the processed image and the reference image. A smaller MSE value indicates better quality.
- Peak Signal-to-Noise Ratio (PSNR) → Used to calculate the ratio between the maximum signal intensity and the amount of noise in a processed image. A higher PSNR value indicates higher visual quality.

The optimal parameter criteria in this study are the configurations that produce the smallest MSE values and the highest PSNR, so that they are expected to be able to produce historical images with better contrast, sharper details, and minimal noise.

A. Research Flowchart

The research workflow for "Optimizing the CLAHE Method and Unsharp Mask Filter for Improving Historical Image Quality" is shown in Figure 1.

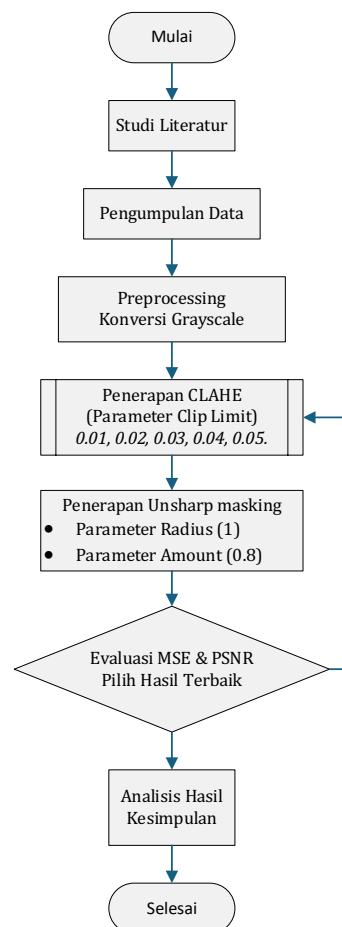
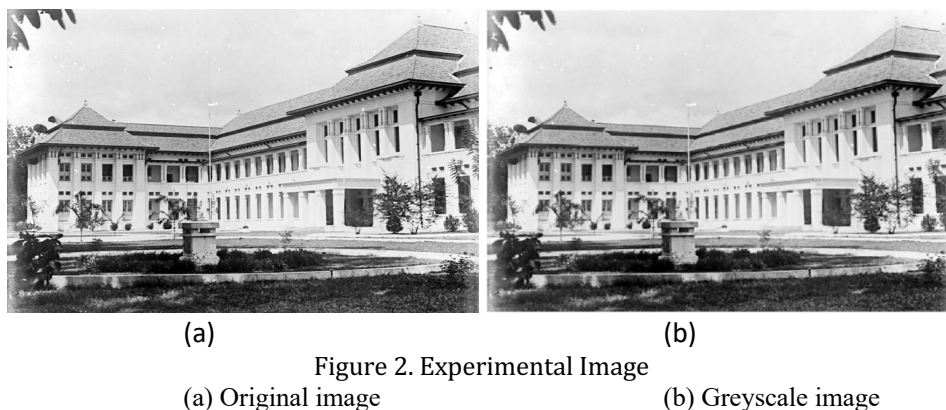


Figure 1. Research Flowchart

The first stage was to conduct a literature review to address the research needs. Data collection included historical images from various sources, including Google. The image input process involved conversion to grayscale images, image enhancement processing using the CLAHE method, and the application of the unsharp mask method. The output image was the result of processing the original image using the CLAHE method combined with the unsharp mask.

3. RESULTS AND DISCUSSION

The first experimental image that was tested is shown in Figure 2.



Performance testing was conducted to identify the optimal CLAHE parameter configuration. Evaluation was conducted on the entire historical image collection by applying a combination of the CLAHE method (with varying clip limits) and Unsharp Masking (with fixed parameters).

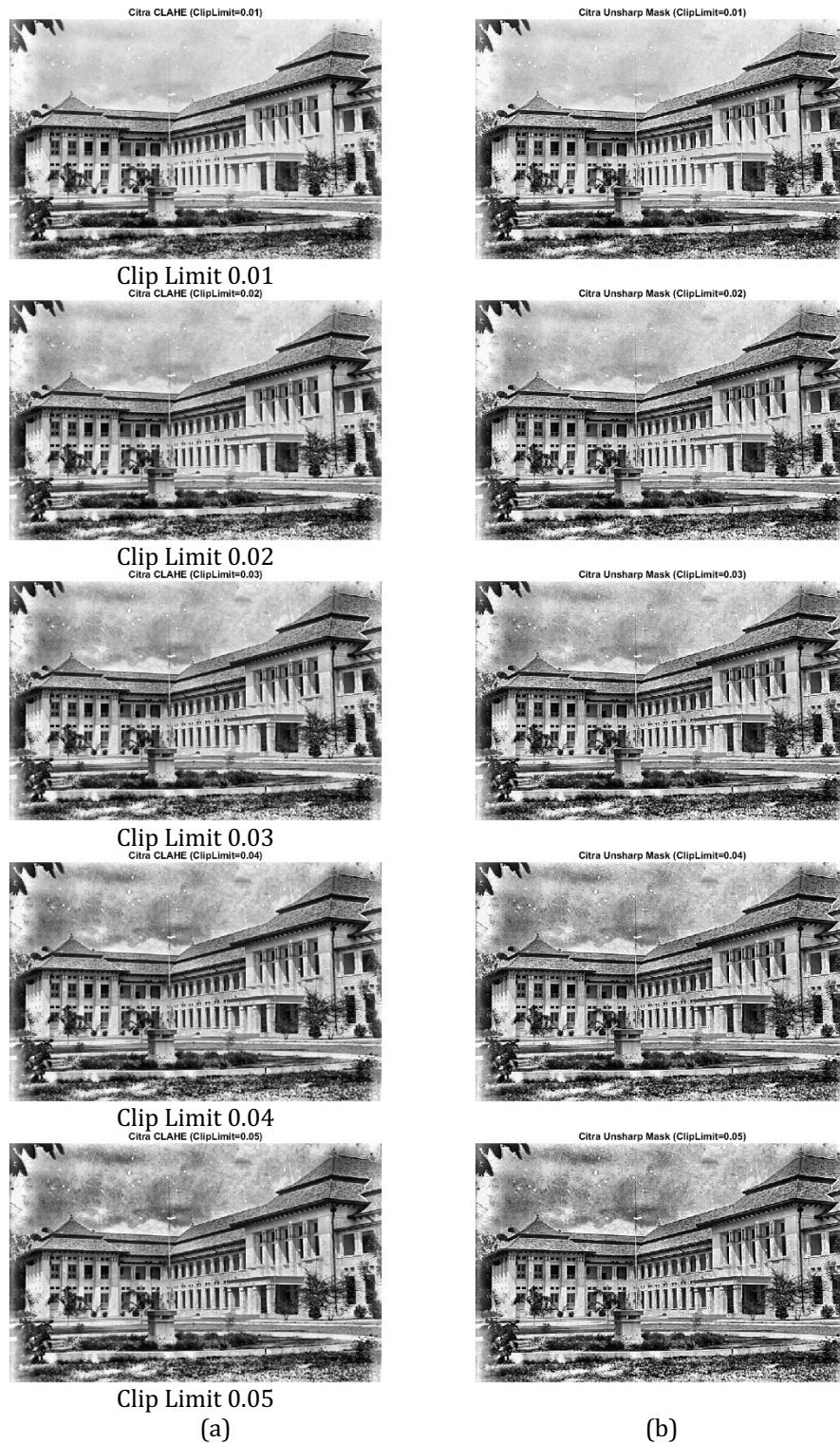


Figure 3. Experimental results with different clip limit parameter values
 (a) With Clip Limit Value (b) Adding the Unsharp Masking filter

The quality of the processed image is then objectively measured using the MSE and PSNR metrics by comparing it to a reference image. The following is a summary of the evaluation results for each clip limit value in the CLAHE method tested:

Table 1. The performance of CLAHE and unsharp masking

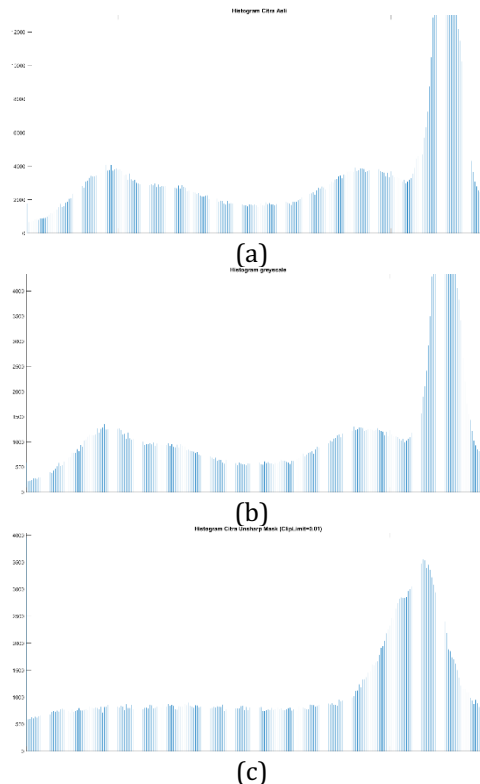
Clip Limit Value	MSE	PNSR (dB)
0.01	1429.5879	16.5787
0.02	2163.4321	14.7794
0.03	2671.6006	13.8631
0.04	3093.2792	13.2266
0.05	3462.6369	12.7367

From the results of the table above, the historical image that has good performance with the smallest MSE results and the highest PNSR is shown in Figure 4.



Figure 4. Results with the best performance

The results of the study show that the results of CLAHE and unsharp mask show histograms that are not as flat as the original image and the greyscale image.



(a) Original image Figure 5. Histogram (b) Greyscale image (c) CLAHE and unsharp mask image

The histogram in Figure 5.c shows a wider and more even distribution in the dark to medium intensity areas. The method shows that the processing successfully increased the image contrast in the dark and gray areas, making details more visible.

4. CONCLUSION

Based on the results presented in the table and discussion, it can be concluded that the clip limit parameter value in the CLAHE method of 0.01 is the most optimal configuration for improving the quality of historical images. This configuration produces the best evaluation metrics, namely the smallest Mean Squared Error (1429.5879) and the highest Peak Signal-to-Noise Ratio (16.5787 dB). These results indicate that the combination of CLAHE with a clip limit of 0.01 and Unsharp Masking is effective in achieving the research objectives, namely, producing historical images with better contrast, sharper details, and minimal noise. Conversely, increasing the clip limit value worsens image quality because it tends to amplify noise and cause an imbalance between contrast and sharpness enhancement, which ultimately reduces overall performance.

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