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Image Quality Restoration on Historical Artifacts Using Histogram Equalization and Contrast Stretching Methods

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Abstract

This research was carried out to improve the image quality of historical artifacts that experience quality degradation such as noise, unclear or dark image contrast, and poor sharpness. Contrast Stretching and Histogram Equalization are image quality improvement methods to expand and even out image grayscale. This research aims to build a system for improving image quality on historical artifacts using contrast stretching and histogram equalization methods. The sample used in this research is RGB image data with 10 test images in .jpg format, while the process uses the Matlab programming language. The results of improving image quality using the contrast stretching and histogram equalization methods from sample 1 to image sample 10 showed the best results in test image_citra_1 with contrast stretching results based on PSNR = 32.61 dB and MSE = 35.86 Db and PSNR = 19.13 Db and MSE = 794.76 in histogram equalization calculations.

Introduction

The development of digital technology has had a major influence on the world of image processing, especially in the context of decreasing the quality of historical artifacts. Historical artifacts are objects created or modified by people in the past that can provide information about their culture, activities or works of art. Artifacts are historical sources that are important for studying the development of human civilization from prehistoric to historical times (Bagby, 2022; Chatulistiwa et al., 2024; A Nurkidam et al., 2022). Artifacts can be made of wood, stone, metal, bronze, animal bones, or others. The forms of artifacts can also vary, such as temples, forts, inscriptions, clothing, tombs, household utensils, currency, manuscripts, ancient writings and other objects (I Gusti Ngurah Agung, 2019; Kusumo, 2023) .

These historical artifacts help learn about how life was in the past and the various cultures and events that occurred at that time (Maulidan & Darmawan, 2024; Kuwoto & Saputra, 2024). However, historical artifacts can experience damage due to natural factors such as age, weather or disasters, as well as human factors such as vandalism or forgery. Therefore, it is important to focus on preserving and improving the image of historical artifacts so that they can be used in the best possible way.

This verse explains that when they were forbidden to cause mischief on the face of the earth, they denied it and claimed that they were people who did good. In fact, they are actually the ones who do damage, but they don't realize it because their hearts and minds are closed.

In an effort to maintain the quality of historical value of historical artefacts, the use of image quality restoration techniques is becoming increasingly important in preserving and reviving the historical essence of historical artefacts (Dutsev, 2021). Image quality restoration is a

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process for repairing images that have experienced a decline in quality due to *noise*, poor contrast, blurring or blurriness. Image restoration is related to the removal or reduction of image degradation that occurs due to the image acquisition process (Sumarni, 2020; Mutaqin & Kom, 2023). Decreased image quality can disrupt the process of interpretation, analysis and recognition of historical artifacts. One method for image quality restoration is *Histogram Equalization* and *Contrast Stretching*. This method has proven effective in increasing the distribution of contrast and *pixel intensity* in an image, thereby improving the visualization of the information contained in the image. The application of *histogram equalization* and *contrast stretching methods* is very relevant in the context of historical artifacts, where color changes and image sharpness provide a more accurate and in-depth view of the past (Yuadi et al. 2023; Suleiman, 2023; Yahaghi et al., 2024).

Sidik et al. (2019) conducted research related to image restoration entitled " Night Image Improvement (Not *Infrared*) Using *Histogram Equalization* and *Contrast Stretching Methods* ". In this research, Siddiq et al created an application program to improve the quality of night images using the method of histogram equalization *and* contrast stretching *to* remove noise with the aim of obtaining an image display with better visualization.

Methods

This study uses the R&D (Research and Development) development research methodology that interprets data through observation and documentation. Observation is a technique of observation carried out directly on an object to seek information and knowledge related to research, especially in research on image quality restoration on historical artifacts using the histogram equalization and contrast stretching methods. The next stage is data collection which involves collecting information, facts, or values from various sources that are relevant to the research objectives. Data collection is carried out by taking as many as 10 image samples that will be restored in quality from a captured mobile phone device. While the process uses the Matlab programming language.

Needs Analysis

Software Requirements

In carrying out image quality restoration using *histogram equalization* and *contrast stretching methods* , this research requires several software. *The* software needed in this research is Matlab R2015a and *the Windows* 11 Operating System *version* 22h2 for x64.

Hardware Requirements

The hardware requirements needed to support this research are the Laptop-VL83DEFO with AMD 3020e processor specifications *with Radeon Graphics* 1.20 GHz and 4.00 GB RAM.

Results and Discussion

Image *Input* Stage

This phase is the beginning of the investigation process by taking pictures. There are several image *files* used in this research, namely JPEG (.jpg) and PNG (.png) format images. The original image and image information are displayed along with the matrix.

Contrast Stretching Process Stage

Contrast Stretching method to improve image quality. *Contrast stretching* is a technique to obtain a new image (s) with better contrast than the original image contrast (r). The idea of *contrast stretching* is to increase the *grayscale* dynamic *range* of the image during processing. In contrast stretching it can be assumed that the image has a gray range between 0 to 255. Points (r1, s1) and points (r2, s2) will determine the form of transformation, and can be adjusted to determine the level of gray level distribution of the resulting image. If r1=s1 and

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r2=s2, then the transformation will be a straight line, which means there is no change in the gray level of the resulting image. In general, it is assumed that r1 ≤ r2 and s1 ≤ s2 so that the function will produce a single value and the value will always increase. The following is an example of a transformation of the Contrast Stretching control:

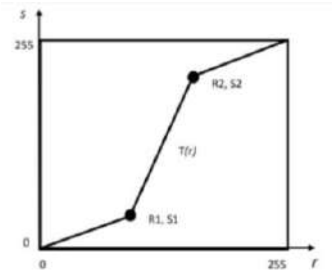


Figure 1. Contrast Stretching Control Transformation (Ramadhan et al., 2023)

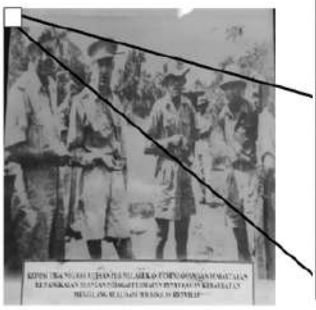
The method used is a linear transformation function with two control points. As previously explained, there are two control points (r1, s1) and (r2, s2) with the assumptions r1 ≤ r2 and s1 ≤ s2, to calculate the value of the transformation results, three functions can be created, namely:

For 0 ≤ r ≤ r1, then s = r $\frac{s1}{r1}$

For r1 ≤ r ≤ r2, then s = s1 + $\frac{(r-r1)*(s2-s1)}{(r2-r1)}$

For r2 ≤ r ≤ 255, then s = s2 + $\frac{(r-r2)*(255-s2)}{(255-r2)}$

Where r is the initial input value and s is the *output* value. The value obtained from the result of the transformation is then stored in an array to be further processed into a new image.



x/y	0	1	2	3	4
0	R=173, G=154, B=148	R=173, G=154, B=147	R=174, G=155, B=148	R=173, G=154, B=147	R=173, G=154, B=147
1	R=172, G=153, B=149	R=173, G=154, B=149	R=173, G=154, B=149	R=172, G=153, B=148	R=172, G=153, B=148
2	R=172, G=153, B=149	R=172, G=153, B=147	R=172, G=153, B=147	R=172, G=153, B=148	R=172, G=153, B=147
3	R=172, G=153, B=149	R=174, G=155, B=149	R=174, G=155, B=149	R=175, G=155, B=150	R=175, G=156, B=150
4	R=172, G=153, B=149	R=173, G=154, B=148	R=174, G=155, B=149	R=173, G=154, B=148	R=172, G=153, B=147

158	158	159	158	158
158	159	159	158	158
158	158	157	158	157
158	160	159	160	160
158	158	159	158	157

Figure 2. Image with RGB and Grayscale Values

grayscale pixel values in the digital image as shown in Figure 4.1 above will be improved in quality with brightness limit values (r1 = 19), (r2 = 254), (s1 = 0), (s2 = 255). So the solution is as follows:

Adjust to the *contrast stretching formula* , namely: (a) For$0 \le r \le r1, maka\ s = r_{r1}^{s1}$; (b) For$r1 \le r \le r2, maka\ s = s1 + (r - r1)_{(r2-r1)}^{(s2-s1)}$; (c) For$r2 \le r \le 255, maka\ s = s2 + (r - r2)_{(255-r2)}^{(255-s2)}$

Formula used$r1 \le r \le r2, maka\ s = s1 + (r - r1)_{(r2-r1)}^{(s2-s1)}$

$$s = s1 + \left(\frac{s2 - s1}{r2 - r1}\right).(r - r1)$$

By substituting r1 = 19, r2= 254, s1= 0, s2 = 255

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$$s = \left(\frac{255}{235}\right).(r - 19) = 1.0851.(r - 19)$$

Calculation for each r Value in the matrix

For r = 157

$$s = 1.0851.(157 - 19) = 1.0851.138 = 149.743 = 150$$

For r = 158

$$s = 1.0851.(158 - 19) = 1.0851.139 = 150.8289 = 151$$

For r = 159

$$s = 1.0851.(159 - 19) = 1.0851.140 = 151.914 = 152$$

For r = 160

$$s = 1.0851.(160 - 19) = 1.0851.141 = 152.999 = 153$$

From the entire *contrast stretching process* above, a resulting image is obtained using the pixel values from the results of this process. As seen in Figure 4.2 below.

Table 1. Initial Image and Improved Image with *Grayscale Contrast Stretching*

158	158	159	158	158
158	159	159	158	158
158	158	157	158	157
158	160	159	160	160
158	158	159	158	157

Results →

151	151	152	151	151
151	152	152	151	151
151	151	150	151	150
151	153	152	153	153
151	151	152	151	150

MSE and PSNR

Mean Square Error (MSE) and *Peak Signal to Noise Ratio* (PSNR) are examples of parameters that are commonly used as indicators to measure the similarity of two images. These parameters are often used to compare image processing results with the initial image or original image. The equation used to calculate these two parameters is as follows:

$$MSE = \frac{1}{m\ x\ n}\sum_{i=0}^{n-1}\sum_{j=0}^{m-1}[f(i,j) - g(i,j)]^2$$

$$PSNR = 10\ log_{10}\frac{255^2}{MSE}$$

The calculated values for MSE and PSNR from *contrast stretching* are as follows:

Where: (a) f(i,j) is the pixel value at position (i,j) of the original image (grayImg); (b) g(i,j) is the pixel value at position (i,j) in the stretched image (stretchedImg); (c) m and n are image sizes, in this case m = n = 5

Table 2. Original Matrix *Pixel*

158	158	159	158	158
158	159	159	158	158
158	158	157	158	157
158	160	159	160	160
158	158	159	158	157

Table 3. *Pixels* after *contrast stretching (StretchedImg)*

151	151	152	151	151
151	152	152	151	151
151	151	150	151	150

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151	153	152	153	153
151	151	152	151	150

Next is to calculate the squared difference for each element as follows:

$(158-151)^2 = 49$

$(158-151)^2 = 49$

$(159-152)^2 = 49$

$(158-151)^2 = 49$

$(158-151)^2 = 49$

$(158-151)^2 = 49$

$(159-152)^2 = 49$

$(159-152)^2 = 49$

$(158-151)^2 = 49$

$(158-151)^2 = 49$

$(158-151)^2 = 49$

$(158-151)^2 = 49$

$(157-150)^2 = 49$

$(158-151)^2 = 49$

$(157-150)^2 = 49$

$(158-151)^2 = 49$

$(160-153)^2 = 49$

$(159-152)^2 = 49$

$(160-153)^2 = 49$

$(160-153)^2 = 49$

$(158-151)^2 = 49$

$(158-151)^2 = 49$

$(159-152)^2 = 49$

$(158-151)^2 = 49$

$(157-150)^2 = 49$

The total squared difference is:

$$49\ x\ 25 = 1225$$

$$MSE = \frac{1225}{25} = 49\ dB$$

$$PSNR = 10\ log_{10} \frac{255^2}{49}$$

PSNR = $10\ log_{10} \frac{65025}{49}$

$$PSNR = 10\ log_{10}(1327{,}04)$$

$$PSNR = 10 \times 3.1236 = 31.236 \text{ dB}$$

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So the MSE and PSNR values from the contrast stretching calculation are MSE = 49dB and PSNR = 31,236 dB

Histogram Equalization **Process Stage**

After carrying out manual calculations for *contrast stretching*, the pixel values will be taken and calculated for *histogram equalization*, the steps are as follows:

Contrast stretching calculation results

Table 4. Matrix 5 x 5 *contrast stretching calculation*

151	151	152	151	151
151	152	152	151	151
151	151	150	151	150
151	153	152	153	153
151	151	152	151	150

From the pixel values in the image matrix, the frequency and cumulative distribution of the gray scale values are calculated. The frequency list and cumulative distribution calculations can be seen in the following table.

Table 5. Frequency and Cumulative Distribution of Gray Scale Values

Gray Scale	Frequency	Cumulative distribution
150	3	3
151	14	3+ 14 = 17
152	5	17 + 5 = 22
153	3	22 + 3 = 25

Calculate the Gray value from the results of the cumulative distribution calculation using the formula previously written above.

$$h1 = round\left(\frac{3\ x\ 2^5\ -3}{5\ x\ 5}\right) = round\left(\frac{87}{25}\right) = 3.48$$

$$h2 = round\left(\frac{17\ x\ 2^5\ -14}{5\ x\ 5}\right) = round\left(\frac{306}{25}\right) = 12.24$$

$$h3 = round\left(\frac{22\ x\ 2^5\ -5}{5\ x\ 5}\right) = round\left(\frac{594}{25}\right) = 23.76$$

$$h4 = round\left(\frac{25\ x\ 2^5\ -3}{5\ x\ 5}\right) = round\left(\frac{725}{25}\right) = 29$$

Calculation results for all gray scale values can be seen in the following table:

Table 6. Gray Scale Value Calculation Results

Gray Scale	Frequency	Grayness of Results
150	3	3.48 => 3
151	14	12.24 => 12
152	5	23.76 => 24
153	3	29

Meanwhile, the image matrix after *the histogram equalization process* is as follows:

Table 7. 5 x 5 *Histogram Equalization Matrix*

12	12	24	12	12
12	24	24	12	12

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12	12	3	12	3
12	29	24	29	29
12	12	24	12	3

Next, to calculate the MSE and PSNR values from *the histogram equalization* are as follows:

The total squared difference is:

$(151-12)^2 = 19.321$

$(151-12)^2 = 19.321$

$(152-24)^2 = 16,384$

$(151-12)^2 = 19.321$

$(151-12)^2 = 19.321$

$(151-12)^2 = 19.321$

$(152-24)^2 = 16,384$

$(152-24)^2 = 16,384$

$(151-12)^2 = 19.321$

$(151-12)^2 = 19.321$

$(151-12)^2 = 19.321$

$(151-12)^2 = 19.321$

$(150-3)^2 = 21.609$

$(150-3)^2 = 21.609$

$(151-12)^2 = 19.321$

$(153-29)^2 = 15.376$

$(152-24)^2 = 16.384$

$(153-29)^2 = 15.376$

$(153-29)^2 = 15.376$

$(151-12)^2 = 19.321$

$(151-12)^2 = 19.321$

$(152-24)^2 = 16,384$

$(151-12)^2 = 19.321$

$(150-3)^2 = 21,609$

$$MSE = \frac{\begin{array}{c}19.321+19.321+16.384+19.321+19.321+19.321+16.384+16.384+19.321+19.321+19.321+19.321+21.609+\\19.321+21.609+19.321+15.376+16.384+15.376+15.376+19.321+19.321+16.384+19.321+21.609\end{array}}{25}$$

$$MSE = \frac{463.369}{25} = 185.347\ dB$$

Because the results of matrix calculations have different results, a comparison of maximum signal power to error power (MSE) is used and the formula is as follows:

$$PSNR = 10\ log_{10} \frac{255^2}{MSE}$$

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$PSNR = 10\ log_{10}\ (255^2)$-10 $log_{10}\ (MSE)$

$PSNR = 10\ log_{10}\ (65025)$-10 $log_{10}\ (MSE)$

$PSNR = 10\ (2\ log_{10}(255))$- 10 $log_{10}\ (MSE)$

$PSNR = 20\ log_{10}(255)$ - 10 $log_{10}\ (185.347)$

$PSNR = 20\ x\ 2.408$ - 10 x 2,268

$PSNR = 48.16$ -– 22.68

$$PSNR = 25.48\ dB$$

So the MSE and PSNR values from *the histogram equalization calculation* are MSE = 185.347 dB and PSNR = 25.48 dB

The result of the improvement processed using the *contrast stretching* and *histogram equalization* methods is that the results of the improvement processed using the *histogram equalization* method show that the superior image results are more obvious because this method can increase the overall contrast by expanding the pixel intensity range in the image so that the entire intensity scale is available more evenly. The results of the correction processed using the *contrast stretching* method show image results that are still unclear because this method does not take into account the overall distribution of pixel intensity.

Result Display

Matlab Application GUI Display

This application has an interface designed to process and analyze the quality of digital images through several methods. At the top left, there is an area to display user-uploaded "Original Images". Below that, there is an " *Image Processing* " panel which contains various buttons for uploading images, changing images from *RGB* to *grayscale* , performing *contrast stretching, histogram equalization* , downloading processed images, and resetting the process. Each of these buttons allows the user to perform various image processing operations sequentially.

The middle and right parts of the application interface are divided into several graphs that display the results of each processing stage. These graphs include *grayscale graphs* , original histograms, *contrast stretching results* , *contrast stretching histogram results* , *equalization histogram results, and equalization* histogram results . In addition, on the right there are two indicator panels that show the *PSNR (Peak Signal-to-Noise Ratio)* and *MSE (Mean Squared Error) values* of the processed image, providing users with quantitative information about the quality of the processing results. This interface is designed to provide a clear and easy to understand visualization of each step in digital image quality improvement.

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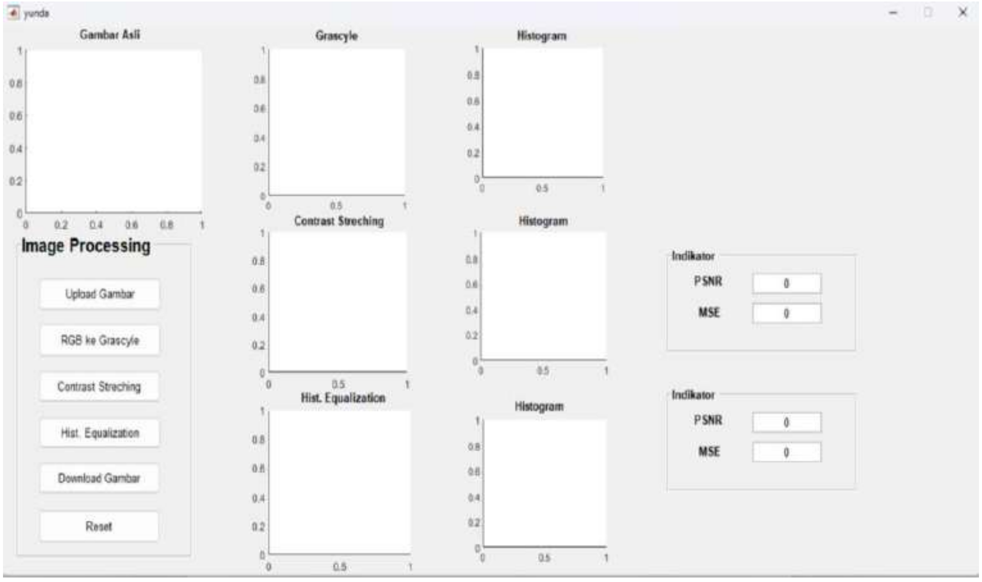

Figure 2. Matlab Application GUI Display

Image Repair Process Display

In this section there are 3 stages of the image improvement process which can be seen in the image below:

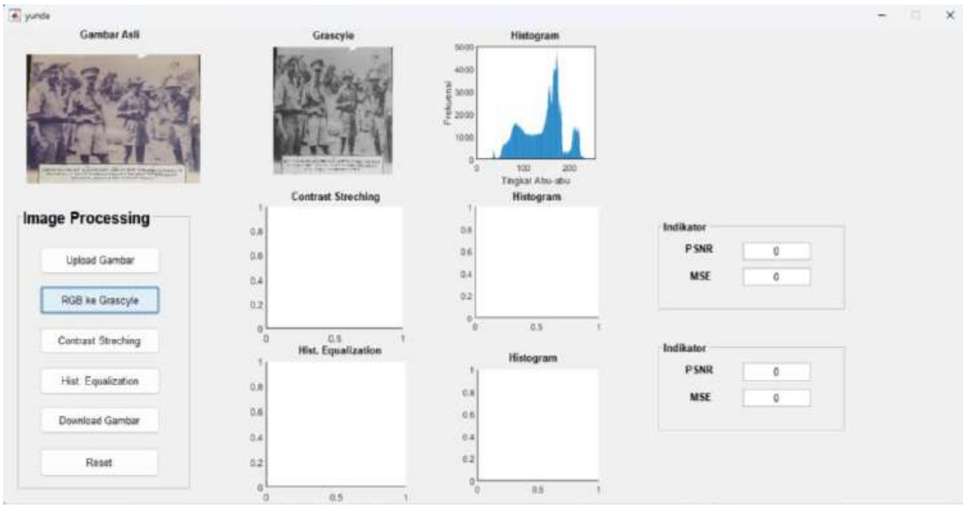

Figure 3. RGB Image Improvement Process to Grayscale

The conversion stage from RGB to *grayscale* in this image involves several important steps that can be accessed through the application interface. First, the user uploads a color (RGB) image using the " *Upload* Image" button in the " *Image Processing* " panel. Once the image is uploaded, users can click the “RGB to *Grayscale* ” button to start the conversion process. This process involves calculating *grayscale* intensity values for each pixel in a color image.

Apart from that, this application also displays a histogram of the resulting *grayscale images.* This histogram shows the distribution of gray levels in a grayscale image and helps users understand how pixel intensity is distributed throughout the image. This histogram can provide a visual representation of the contrast and brightness of an image.

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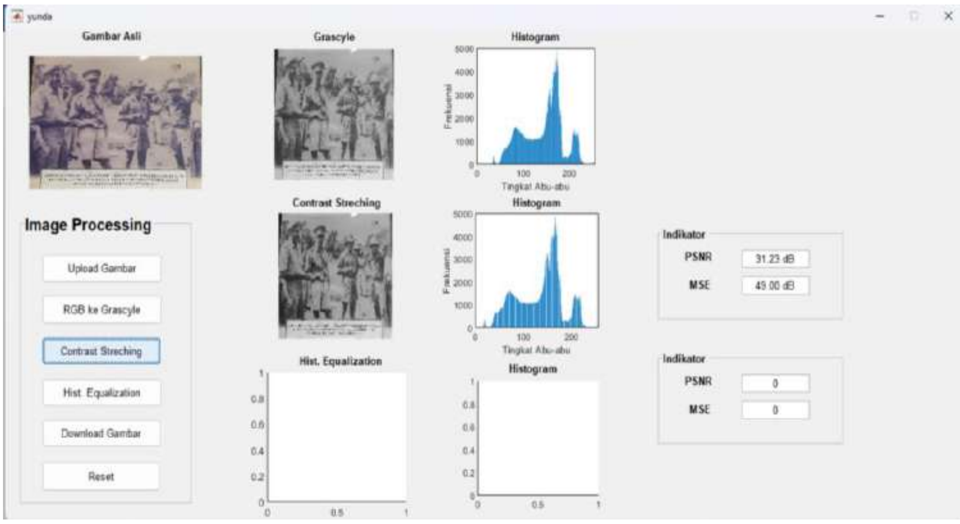

Figure 4. Contrast Stretching Repair Process

At the bottom of the *grayscale image* , there is the result of the " *Contrast Stretching* " stage, which is a technique for improving image contrast. These results are displayed under the label " *Contrast Stretching* ", and a histogram of these results is displayed to the right of them, showing the distribution of gray levels after the contrast is increased.

On the right, there are two indicator panels that display the PSNR (*Peak Signal-to-Noise Ratio*) and MSE (*Mean Squared Error*) values of the processed image, providing users with quantitative information about the quality of the processing results. This interface allows users to easily follow and understand each step in the digital image quality improvement process.

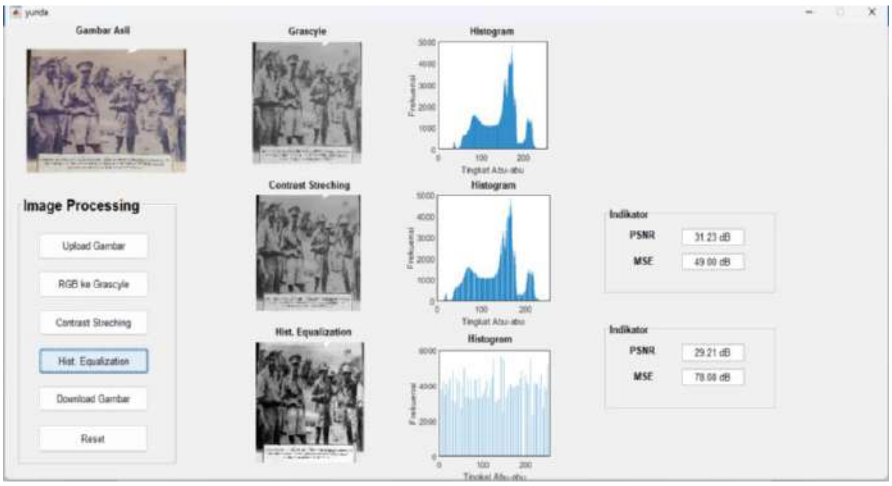

Figure 5. Histogram Equalization Improvement Process

In this section, you will see images that have been processed using the *histogram equalization technique* . This image usually has better contrast compared to the original image or *grayscale image* , because the pixel intensity distribution has been flattened.

Next to the *histogram equalization results image* , there is a histogram showing the new distribution of pixel intensity after the *equalization process* . This histogram is usually more even than the histogram before *equalization* , indicating that pixel intensities are spread more widely across the range of grayscale values.

Test result

Testing will be carried out using several different image sizes and using different methods. Following are the results of the tests carried out. The input image is an image that has low contrast, which makes details in the image difficult to distinguish. Light and dark areas do not

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have clear differences, making the image look flat. then testing or improvement is carried out by adjusting the contrast. The following are the results after repairs.

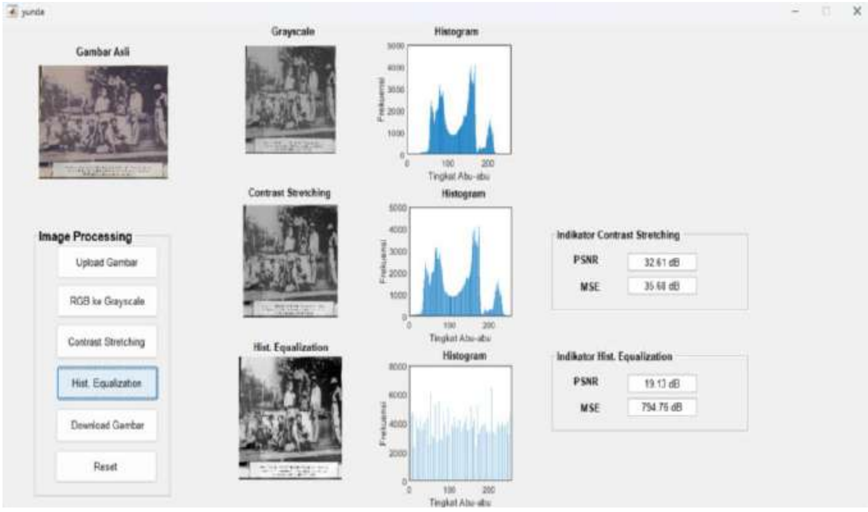

Figure 6. Test Results test_citra_1

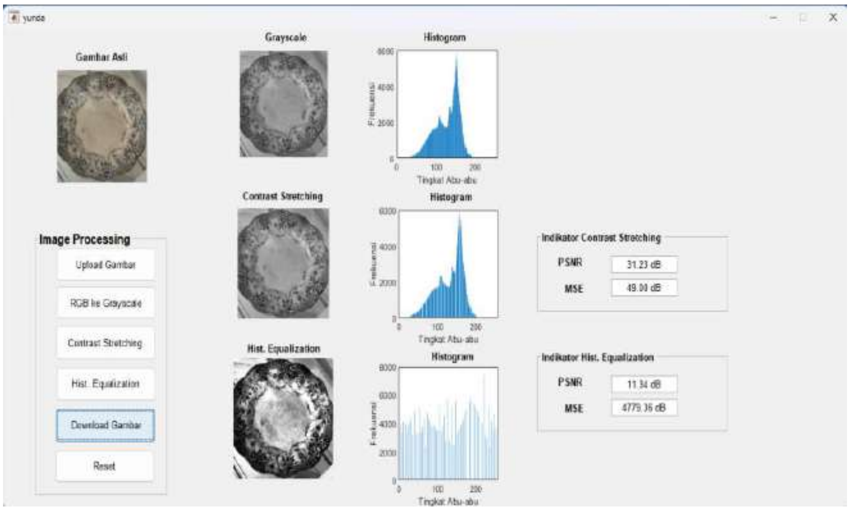

*Figure 7. Testing Results test_citra_*

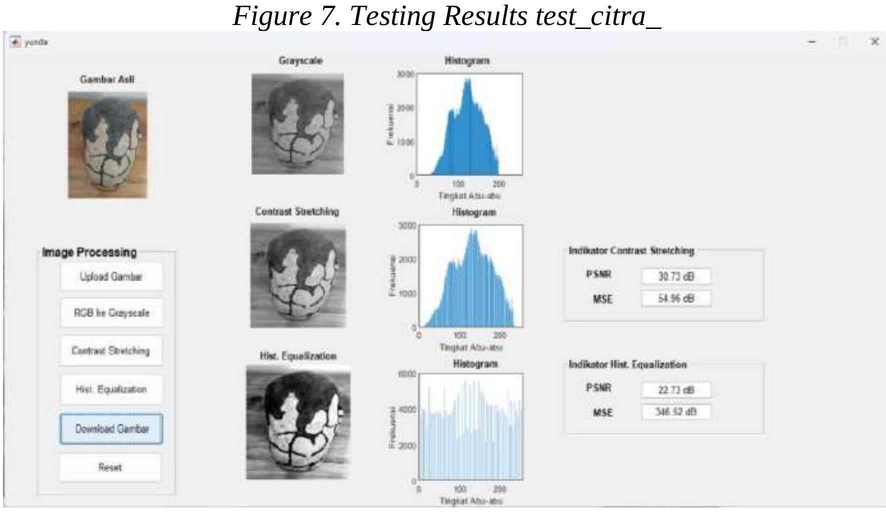

Figure 8. Test Results test_citra_3

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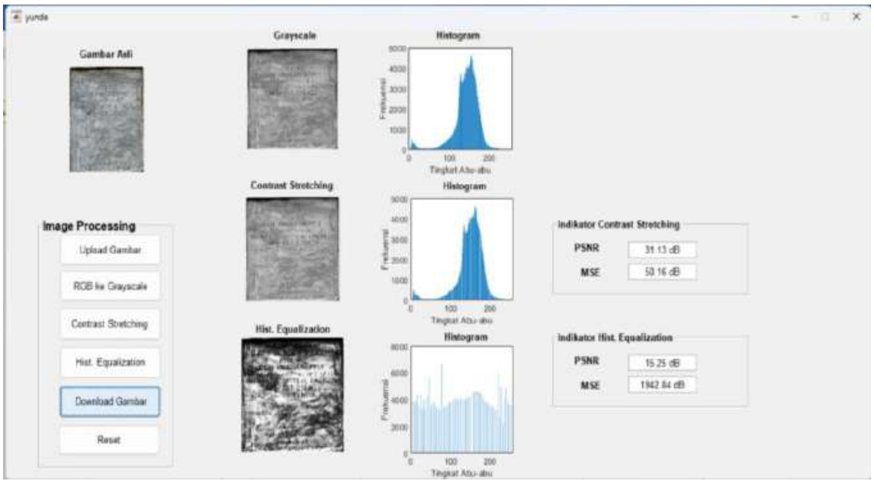

Figure 9. Test Results test_citra_4

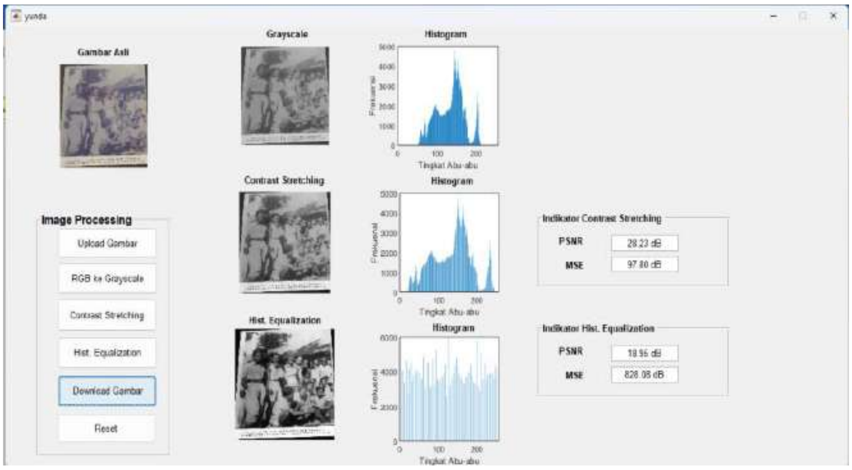

Figure 10. Test Results test_citra_5

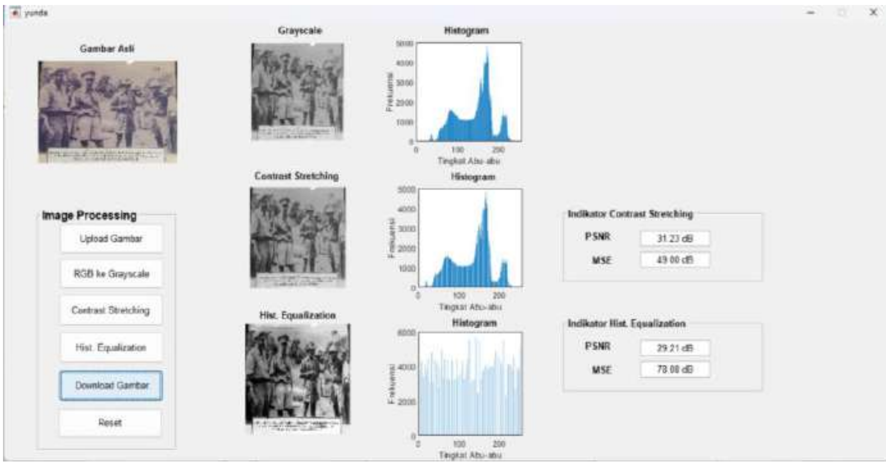

Figure 11. Test Results test_citra_6

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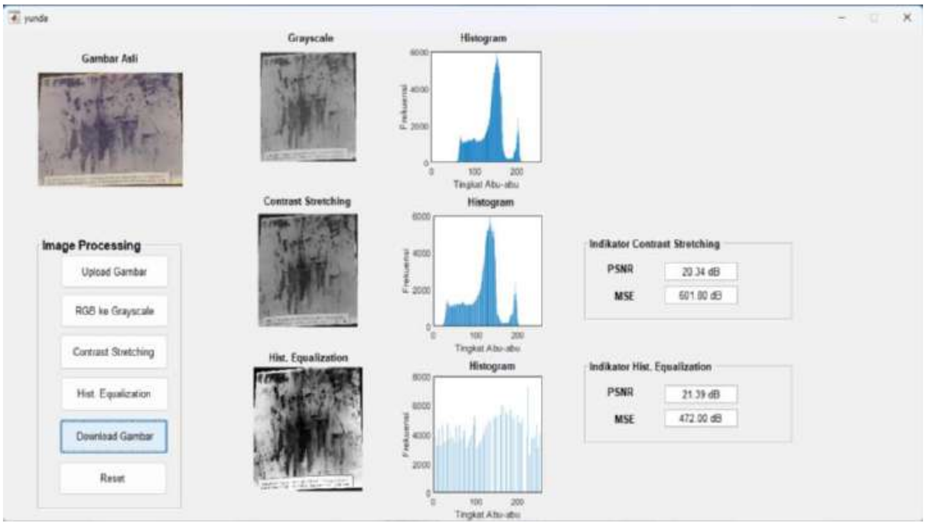

Figure 11. Test Results test_citra_7

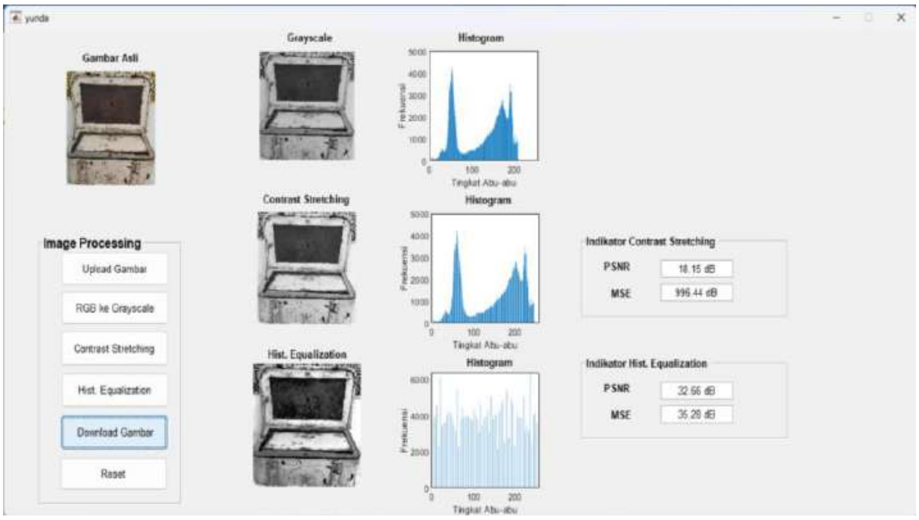

Figure 12. Test Results test_citra_8

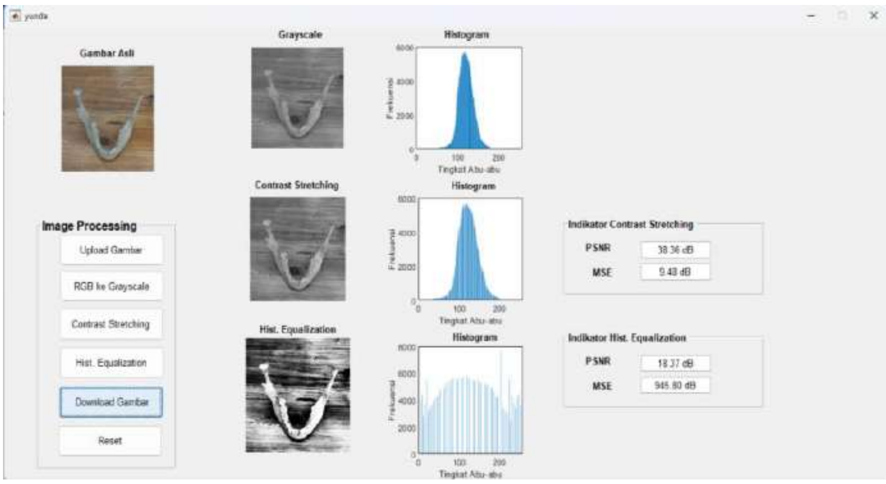

Figure 13. Test Results test_citra_9

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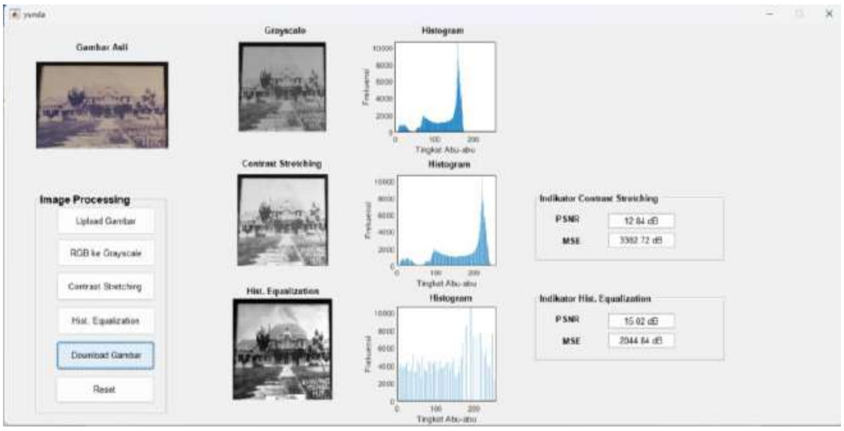
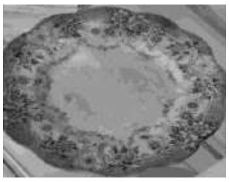
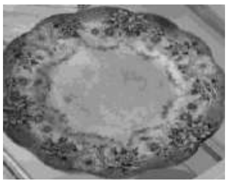


Figure 14. Test Results test_citra_10

The image above shows a digital image that has been processed with *Contras Stretching* and *Histogram Equalization* , and the original image with minimal light intensity then produces a brighter and clearer image. The histogram also shows graphic changes from the original RGB image, *grayscale image* , *contrast stretching image* and *histogram equalization image* so that changes can be seen in the image histogram.

Table 8. Image Testing Results

No	Image *File* Name	*Grayscale*	CS	HE
1	 test_image_1			
2	 test_image_2			
3	 test_image_3			
4	 test_image_4			

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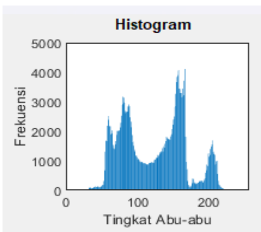
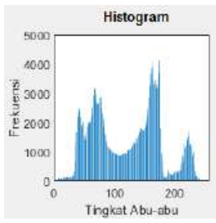
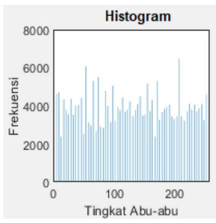
5	 test_image_5			
6	 test_image_6			
7	 test_image_7			
8	 test_image_8			
9	 test_image_9			
10	 test_image_10			

Table 9*Grayscale* Image Histograms , *Contrast Stretching* and *Histogram Equalization*

No	Image *File* Name	*Grayscale*	CS	HE
1	test_image_1			
2	test_image_2			

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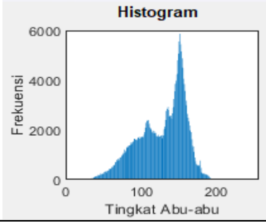
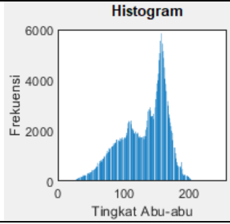
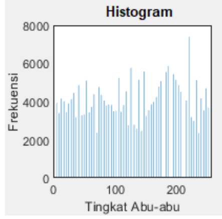
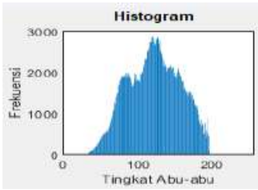
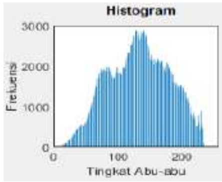
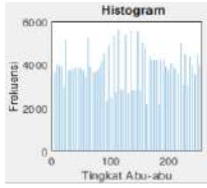
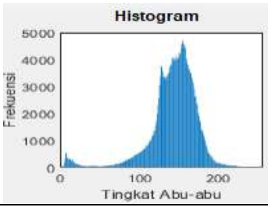
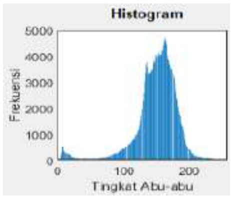
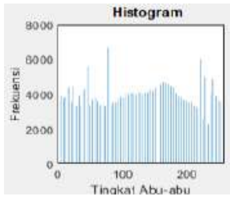
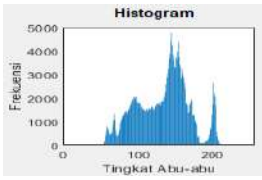
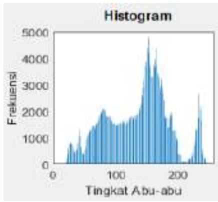
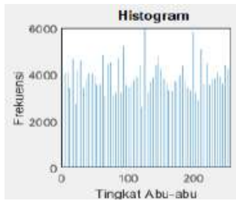
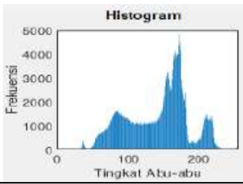
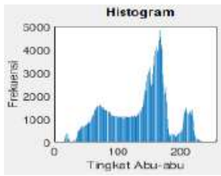
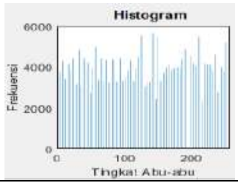
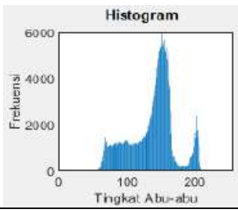
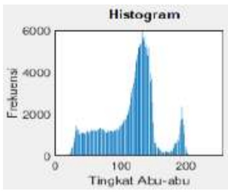
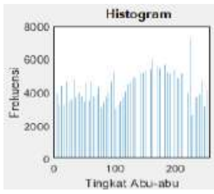
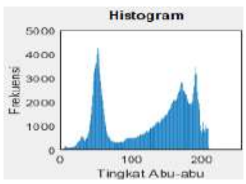
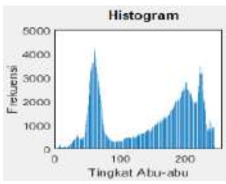
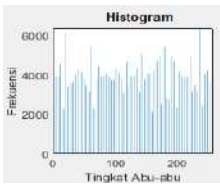
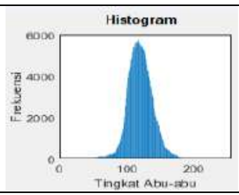
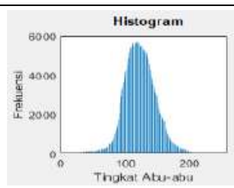
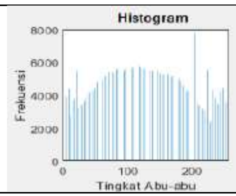
				
3	test_image_3			
4	test_image_4			
5	test_image_5			
6	test_image_6			
7	test_image_7			
8	test_image_8			
9	test_image_9			

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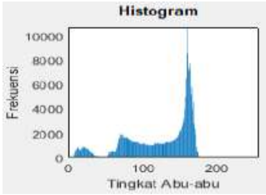
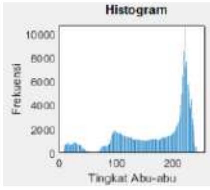
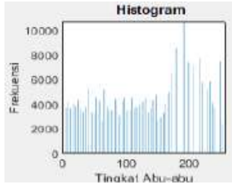
10	test_image_10			

Table 10PSNR and MSE *Contrast Stretching* and *Histogram Equalization Values*

No	Image *File* Name	Indicator			
		Contrast Stretching		***Histogram Equalization***	
		PSNR	**MSE**	**PSNR**	**MSE**
1	test_image_1	32.61	35.68	19.13	794.76
2	test_image_2	31.23	49.00	11.34	4779.36
3	test_image_3	30.73	54.96	22.73	346.52
4	test_image_4	31.13	50.16	15.25	1942.84
5	test_image_5	28.23	97.80	18.95	828.08
6	test_image_6	31.23	49.00	29.21	78.08
7	test_image_7	20.34	601.80	21.39	472.00
8	test_image_8	18.15	996.44	32.66	35.28
9	test_image_9	38.36	9.48	18.37	945.80
10	test_image_10	12.84	3382.72	15.02	2044.84

Conclusion

From the discussion in the previous chapters, finally the research in this thesis can draw several conclusions, including: (1) The Histogram Equalization and Contrast Stretching methods have proven to be effective in improving the quality of digital images on historical artifacts that experience quality degradation due to noise , poor contrast, or opacity ; (2) From the analysis and testing carried out, both the Histogram Equalization and Contrast Stretching methods can improve the distribution of image pixel intensity. However, its effectiveness may vary depending on the characteristics of the restored image ; (3) Implementation of the method on 10 image samples shows a significant increase in visual quality, which can be seen from the difference in histograms before and after application of the method ; (4) The use of MATLAB software proved adequate for processing digital images and applying the selected methods, thus enabling researchers to carry out restoration more efficiently ; (5) From the results of the testing process it was found that the image test_citra_1.jpg showed the best results with a PSNR value of 32.61 dB and an MSE value of 35.68 dB for the contrast stretching process and a PSNR value of 19.13 dB and an MSE value of 794.76 dB in the histogram equalization calculation although The psnr and mse values for this method are not as good as the Contrast Stretching method , this image still has better quality compared to other test images.

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