



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

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Abstract

The aim of this research was to enhance the image quality of historical objects that undergo quality decline such as noise, low contrasting images, and poor sharpness. Contrast stretching and Histogram equalization are two methods of image enhancement which is used to expand and smooth out the grayscale of an image. The purpose of this study is to develop a system for enhancing the quality of images of historical heritage objects applying contrast stretching and histogram equalization techniques. Concerning the selection of the sample in this research, the data is RGB image data with a total of 10 test images in .mat file format and the process employed is in Matlab programming language. The stimulation of neuron is in jpg format. The works on the contrast stretching and histogram equalization from the sample 1 to sample 10 image the results were highest on test image_citra_1 with the contrast stretching results on the base of PSNR = 32. DOS, = 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 (Afrina, 2022; Chatulistiwa et al., 2024; Nosirovna 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 (Kipfer, 2021).

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 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; Jinjin et al., 2020). 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 (Ningsi, 2020; Yahaghi et al., 2024).

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

The research strategy adopted in this study was the research and development (R&D), which is appropriate with the type of research conducted. The R&D methodology is the cyclical simultaneous designing, development stimulating technique building process in order to meet the research goals and objectives, The experiments used in enhancing historical artifact images through the contrast stretching and histogram equalization techniques. Chosen methodology is a result of the study's objectives, which are to not only evaluate these image processing techniques but also to provide working method that can be used in similar cases in digital heritage preservation.

The sample of the study consisted of 10 digital images of artifacts that were chosen to cover a broad range of common image degradation problems such as low contrast, noise and image blurring. The depicted scenes were either collected from digital resources that can be accessed without violating any copyright or took using an HD camera of a mobile phone. All the images were RGB format, and the dimensions of the image were fine for analysis work on this image. All the images used in this work were chosen with a certain level of image degradation to compare the efficiency of enhancement techniques. Although the sample size in this study was rather small, this was done deliberately in order to perform a detailed analysis of the efficiency of the applied methods and to set grounds for the further research with much larger data sets.

Software and Hardware Requirements

All the image processing tasks were achieved in MATLAB R2015a because it is one of the most preferred tools in the field of Digital Image Processing due to its rich set of libraries and powerful features for image analysis. MATLAB was chosen because of its capability of solving algorithms and analyzing big data set with ease. The software environment provided full control for the application of the image enhancement parameters which included the contrast stretching and the process of histogram equalization for all the samples. For the purpose of hardware setup, I had a laptop with AMD 3020e processor and Radeon Graphics coupled with 4. English: 00 GB of RAM The device is operating on MS Windows 11 Operating System with the windows version being 22h2 for x64. It was evident that this configuration was enough to perform the computational load required for image processing and achieve optimal performance and short processing time. The selection of the hardware was done taking into consideration that the used components can easily be found by

practitioners in the field who potentially use similar setups for practical digital preservation activities.

Contrast Stretching Method

Contrast stretching is one of the methods of enhancing the contrast of an image through an increase in the dynamic range of the grayscale level. As you may remember, this method is more effective on images with low contrast where details on the shadows and high light areas are hardly visible. Nonlinear transformation was used in this study through the application of a linear transformation function with two control points (r_1, s_1) and (r_2, s_2) to manipulate the original intensity values into a new range that improves on contrast. By evaluating each picture carefully, the areas where control was exerted were selected with a view of achieving the maximum effects in every picture.

It had three forms, namely; (1) Compute the minimum (r_1) and maximum (r_2) pixel intensity values of the original image; (2) Perform the linear transformation function that maps r_1 to s_1 and r_2 to s_2 ; (3) Apply the equation uniformly over the entire image resulting in a contrast enhanced image. This was inline with modern method of contrast stretching in which an automatic stretching is applied to the image without taking equal transformation to different images.

Histogram Equalization Method

Histogram equalization is one of the most common methods of improving the image contrast since it adjusts intelligently the pixel density in the picture. This method operates by predigesting the histogram of the image, pushes most frequent intensity values apart and also improves the contrast of the image in general. To further enhance the image quality of the tested images histogram equalization was applied after contrast stretching to balance out pixel intensity and bring out details from the entire grayscale range.

The following were done to perform the above process; (1) Computing the histogram of the pixel intensities of the contrast-stretched image (2) Estimation of the cumulative distribution function (CDF) of the histogram (3) Mapping of the pixel intensities by using the estimated CDF to arrive at an image with equalized contrast. By applying the histogram equalization after the contrast stretching, the study therefore got to widen the global as well as achieving the local contrast, thus giving improved images.

Analysis of Results

The effectiveness of the image enhancement techniques was evaluated using two standard metrics: Two quantitative measurement parameters are used for objective evaluation of the performance of reconstructed image: Peak Signal-to-Noise Ratio (PSNR) and Mean Square Error (MSE). PSNR calculates signal to noise ratio through the ratio of the full power of the signal (in the compression context, the original image) and the power of the interfering noise (the difference between the original and the enhanced image). It is easier to conclude that, the higher PSNR value implies that the image quality of the recovered image is better. On the other hand, MSE calculates the mean of squares of errors which is simply sum of the squared differences between the original and enhanced image. Lower MSE means less error and therefore, the quality of the output is observed to be considerably high. These ratios were found out from each image before and after the enhancement procedures to give a quality stage as to the degree of enhancement. Thus, the outcomes were compared to define the efficiency of contrast stretching and histogram equalization without and with their combination.

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 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:

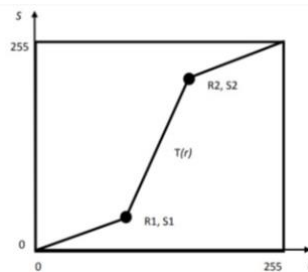


Figure 1. Contrast Stretching Control Transformation (Ramadhan et al., 2023)

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:

$$\text{For } 0 \leq r \leq r_1, \text{ then } s = r \frac{s_1}{r_1}$$

$$\text{For } r_1 \leq r \leq r_2, \text{ then } s = s_1 + \frac{(r-r_1)*(s_2-s_1)}{(r_2-r_1)}$$

$$\text{For } r_2 \leq r \leq 255, \text{ then } s = s_2 + \frac{(r-r_2)*(255-s_2)}{(255-r_2)}$$

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.

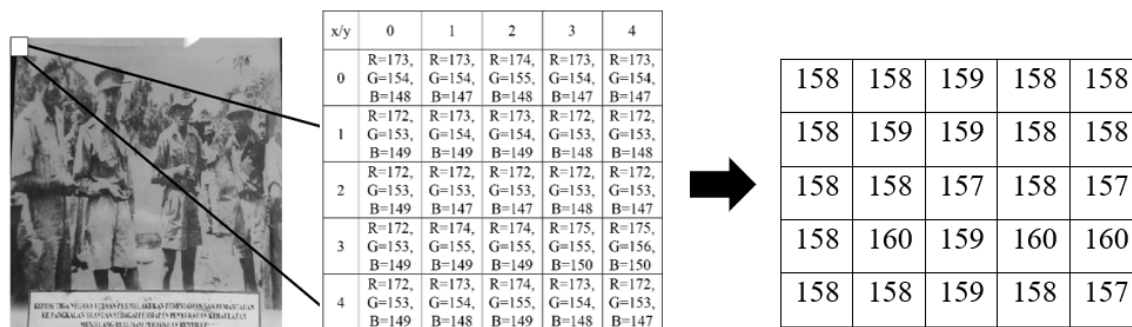


Figure 2. Image with RGB and Grayscale Values

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 $0 \leq r \leq r1$, maka $s = r_{r1}^{s1}$; (b) For $r1 \leq r \leq r2$, maka $s = s1 + (r - r1) \frac{(s2 - s1)}{(r2 - r1)}$; (c) For $r2 \leq r \leq 255$, maka $s = s2 + (r - r2) \frac{(255 - s2)}{(255 - r2)}$

Formula used $r1 \leq r \leq r2$, maka $s = s1 + (r - r1) \frac{(s2 - s1)}{(r2 - r1)}$

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

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

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

Calculation for each r Value in the matrix

For r = 157

$$s = 1.0851 \cdot (157 - 19) = 1.0851 \cdot 138 = 149.743 = 150$$

For r = 158

$$s = 1.0851 \cdot (158 - 19) = 1.0851 \cdot 139 = 150.8289 = 151$$

For r = 159

$$s = 1.0851 \cdot (159 - 19) = 1.0851 \cdot 140 = 151.914 = 152$$

For r = 160

$$s = 1.0851 \cdot (160 - 19) = 1.0851 \cdot 141 = 152.999 = 153$$

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	Results \longrightarrow	151	151	152	151	151
158	159	159	158	158		151	152	152	151	151
158	158	157	158	157		151	151	150	151	150
158	160	159	160	160		151	153	152	153	153
158	158	159	158	157		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:

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

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

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
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:

$$49 \times 25 = 1225$$

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

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

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

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

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

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.

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

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

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

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

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
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:

$$(151-12)^2 = 19.321$$

$$(151-12)^2 = 19.321$$

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

$$(151-12)^2 = 19.321$$

$$(151-12)^2 = 19.321$$

$$(151-12)^2 = 19.321$$

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

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

$$(151-12)^2 = 19.321$$

$$(151-12)^2 = 19.321$$

$$(151-12)^2 = 19.321$$

$$(151-12)^2 = 19.321$$

$$(150-3)^2 = 21.609$$

$$(150-3)^2 = 21.609$$

$$(151-12)^2 = 19.321$$

$$(153-29)^2 = 15.376$$

$$(152-24)^2 = 16.384$$

$$(153-29)^2 = 15.376$$

$$(153-29)^2 = 15.376$$

$$(151-12)^2 = 19.321$$

$$(151-12)^2 = 19.321$$

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

$$(151-12)^2 = 19.321$$

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

$MSE =$

$$\frac{19.321+19.321+16.384+19.321+19.321+19.321+16.384+16.384+19.321+19.321+19.321+19.321+21.609+19.321+21.609+19.321+15.376+16.384+15.376+15.376+19.321+19.321+16.384+19.321+21.609}{25}$$

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

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:

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

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

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

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

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

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

$$PSNR = 48.16 - 22.68$$

$$PSNR = 25.48 \text{ dB}$$

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.

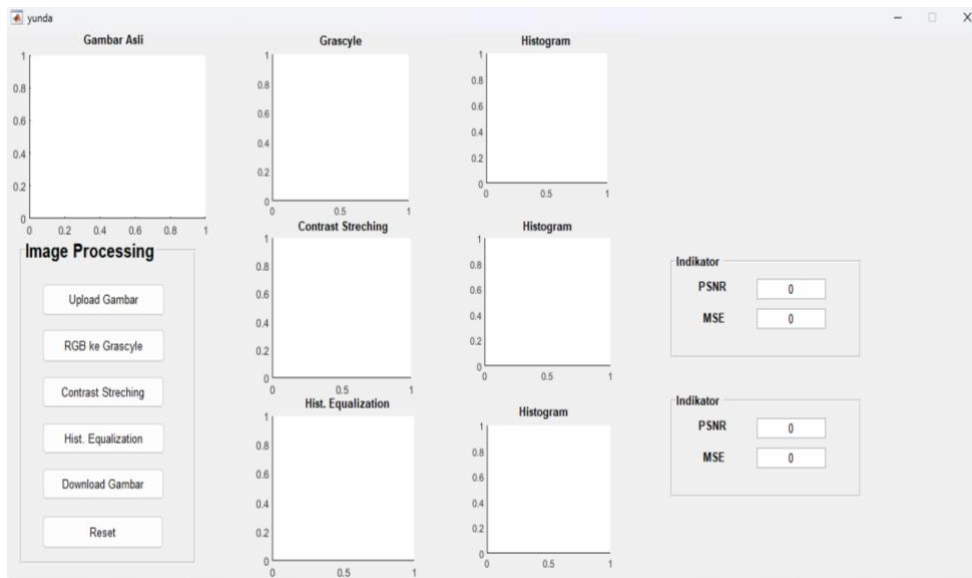


Figure 3. Matlab Application GUI Display

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.

Image Repair Process Display

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

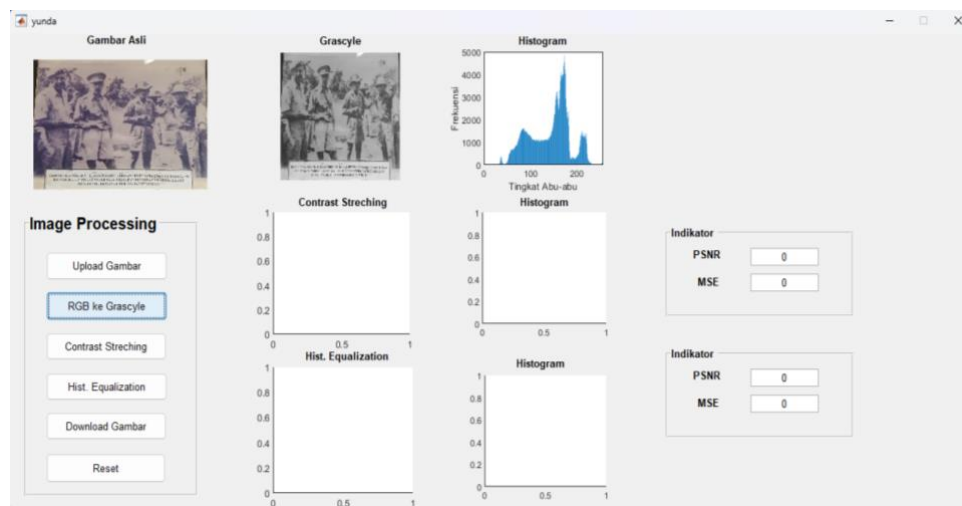


Figure 4. RGB Image Improvement Process to Grayscale

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.

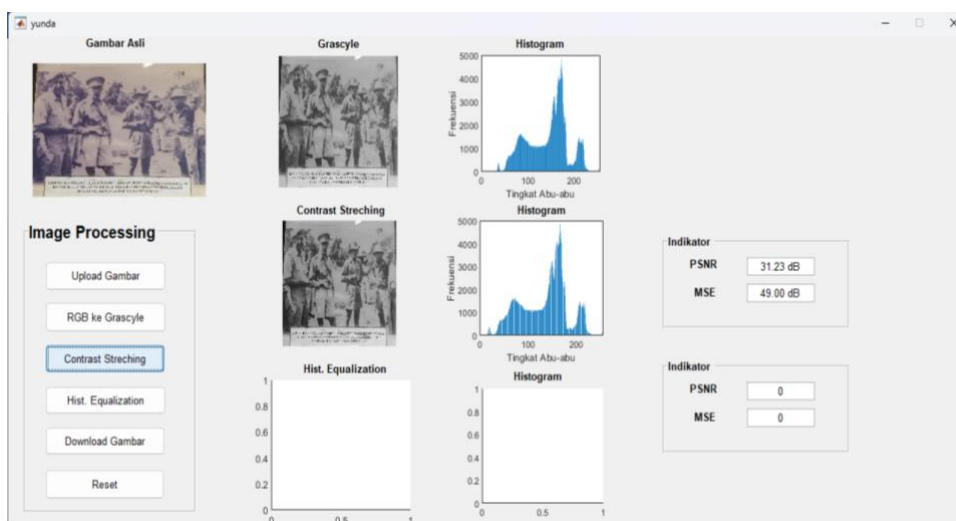


Figure 5. Contrast Stretching Repair Process

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.

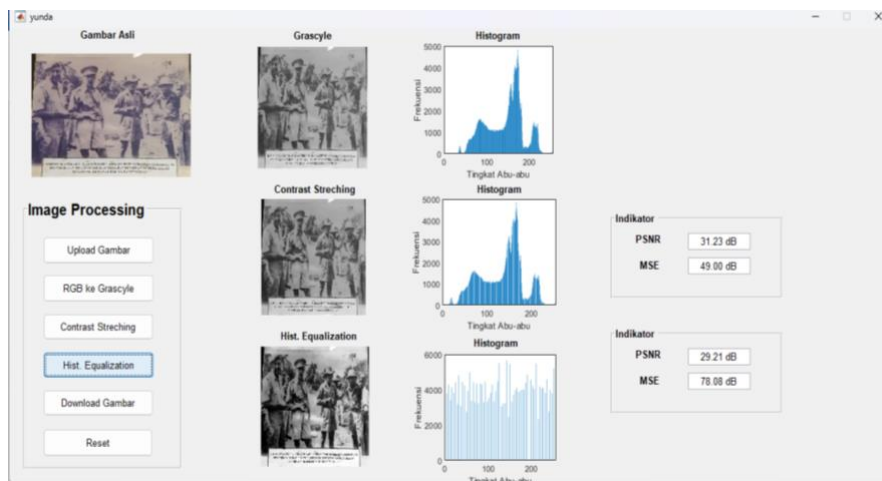


Figure 6. Histogram Equalization Improvement Process

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

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 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.

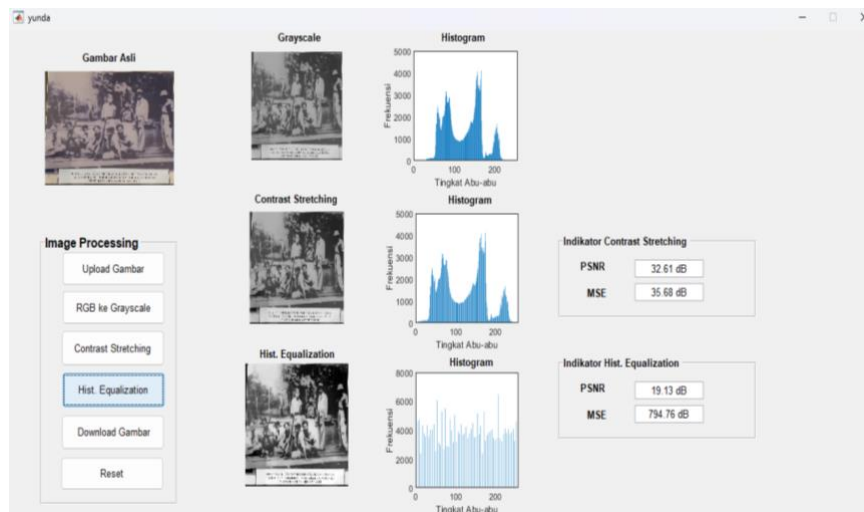


Figure 7. Test Results test_citra_1

This figure shows the processed image after tested on the first test image with two methods, namely contract enhancement by using image stretching & histogram equalization. This is quite evident in the revised image in that the contrast seems to be low such that it appears to be challenging to distinguish areas of high brightness from areas of low brightness. In the resultant image after processing it is clear that the brightness and sharpness of the picture has greatly improved especially the shaded parts. The contrast stretching has favored the dynamic of the grayscale and the histogram equalization makes the pixel intensity even more equilibrated resulting in an aesthetically pleasing image.

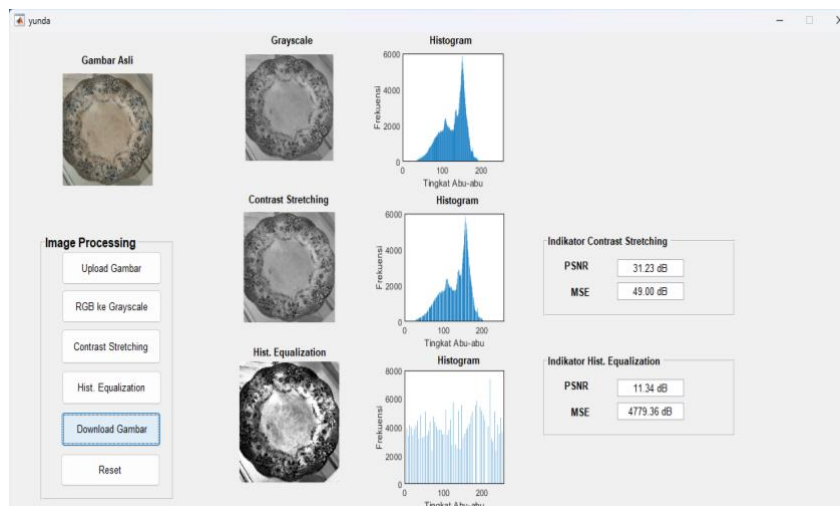


Figure 8. Testing Results test_citra_2

In this figure the second test image is test_citra_2 which is processed in a similar way to the first. First, contrast ratio is relatively low which leads to such image being nearly featureless, and the reader cannot distinguish details. The contrast stretching amplifies the gray-scale range as applied in the image above while the histogram equalization enhances the image by equalizing the pixel density in the grey scale. This leads to improved average image contrast

and fine structure preservation, even in dark regions where no other methods were able to preserve details.

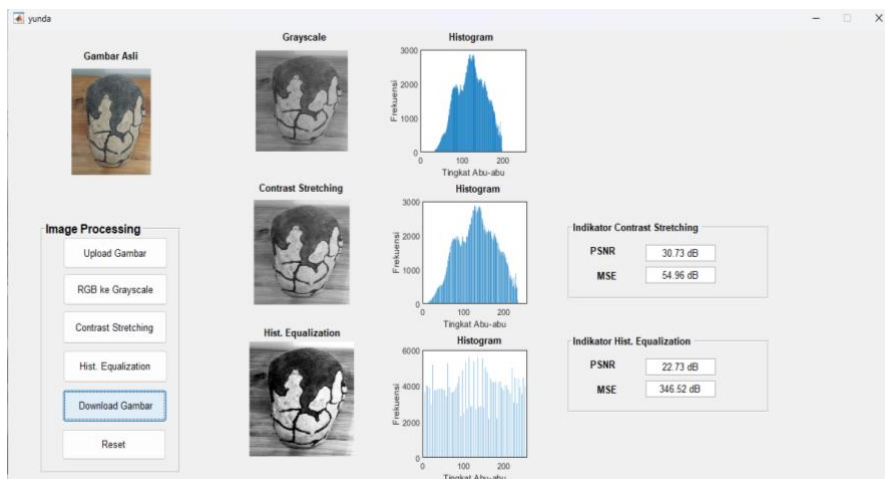


Figure 9. Test Results test_citra_3

This figure illustrates the results of applying the third test image which is test_citra_3. As with the previous ones, the original image has clear problems with contrast, and difficult to see the intricacies. The contrast stretching method improves the contrast thereby increasing the true black areas and making details which were indistinguishable clearer. There is an improvement of the contrast and details in the equalization of the pixel intensity in the histogram, in other words there is an enhancement of the mid-tone and shadow areas of the image.

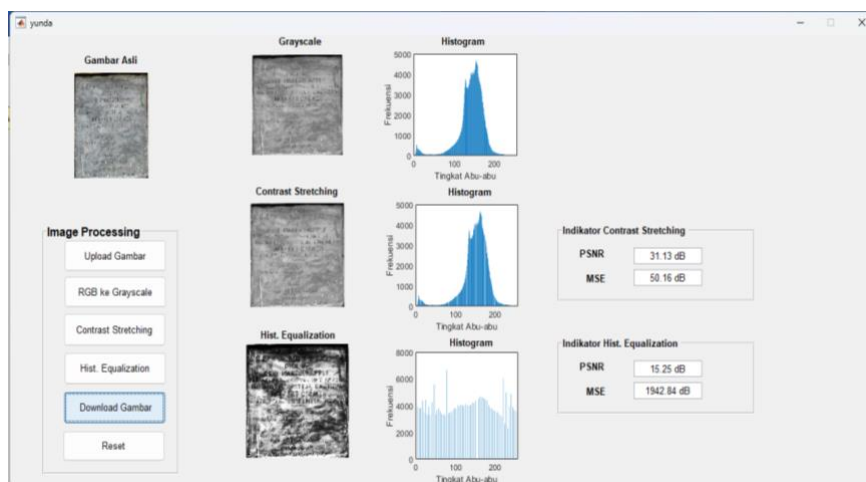


Figure 10. Test Results test_citra_4

The fourth test image is test_citra_4, the results of which is depicted in the figure below; the figures shows the results after processing it through the system. At first, due to the low contrast, it proved inconvenient to distinguish between separate details of the image. The contrast stretching method is successful in expanding the grey level histogram range and as a result improving the contrast. After the subsequent histogram equalization, the intensity distribution of the image is normalized for producing a decreased noisy and expanded image. Little subtle gradations of tone are something that are rendered with increased clarity from the patch up.

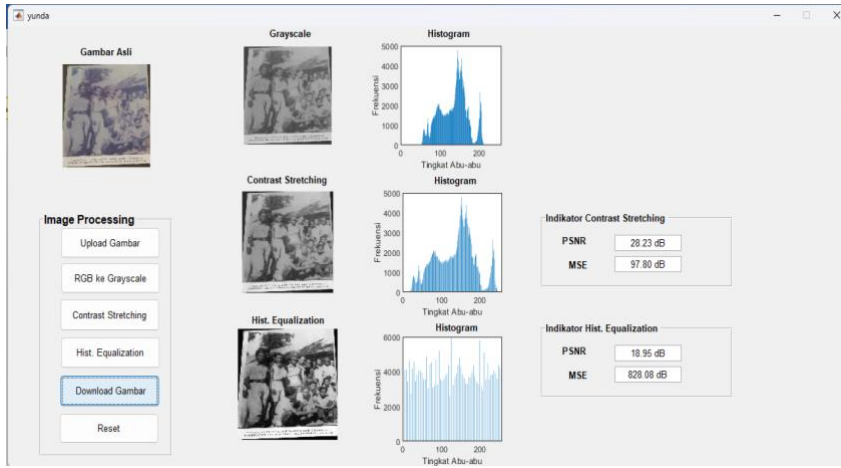


Figure 11. Test Results test_citra_5

Here the fifth test image is test_citra_5 This test image first goes through contrast stretching and then histogram equalization. The contrast of the original image was left low and for this reason there wasn't much detail and clarity in the image. After applying processing, the contrast stretching method enhances the gray level functionality and therefore makes the images brighter and sharp. The histogram equalization then equalises the pixel intensities which in turn increases the contrast of the image and reveals areas of the image that could not have been seen before. The overall result of such features and effects is that the images seem visually balanced with more detail incorporated in the images.

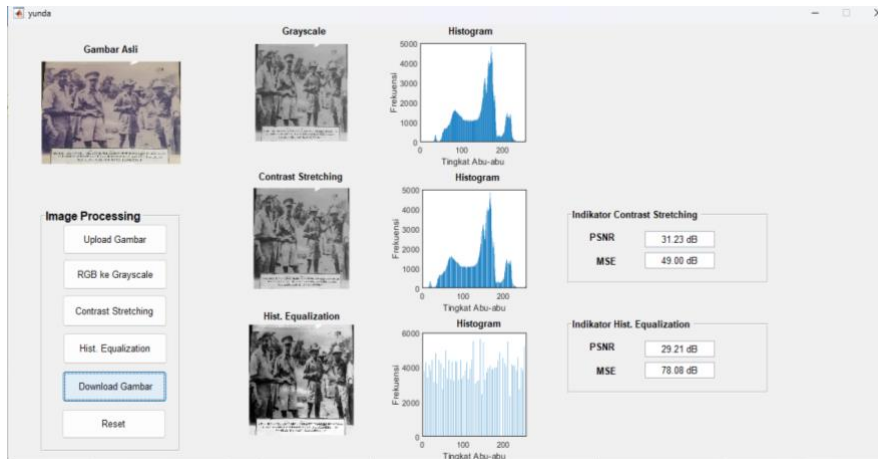


Figure 12. Test Results test_citra_6

The figure below shows the result obtained when applying the proposed method on the sixth test image, namely test_citra_6. They include noise and poor contrast of the original image thus making it difficult to distinguish some of the details in the image. Contrast stretching amplifies the grayscale domain and yields a better and brighter image as shown in the given method. The histogram equalisation then goes a step ahead and smoothes out the image in as far as the pixel intensities are concerned. The last final outcome, therefore, is a greater definition and a much more realistic depiction of the tone variety range between tests and blacks.

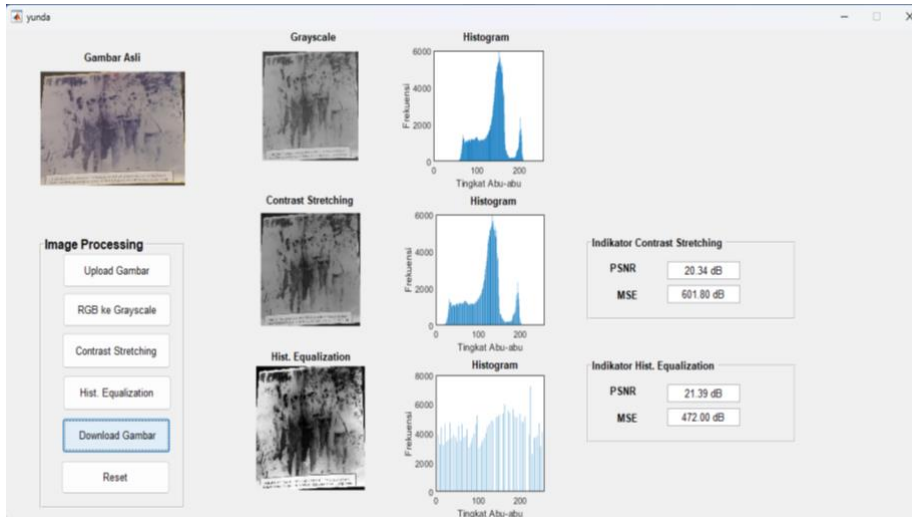


Figure 13. Test Results test_citra_7

Figure 13 below shows the processed outcomes of the seventh test image which is referred to as test_citra_7. The source image is low in contrast reducing the overall image detail and produces a rather plain outlook. The contrast stretching method enhances the dynamic range thus making the image to be more bright and contrasted. The histogram equalization is then applied which improves the contrast of the image even more because it adjusts the intensities of the pixels, making the image much more clear and visually satisfying. There are some margins in the tones esoterically which before created health confusion but in this edition, they are distinguishable.

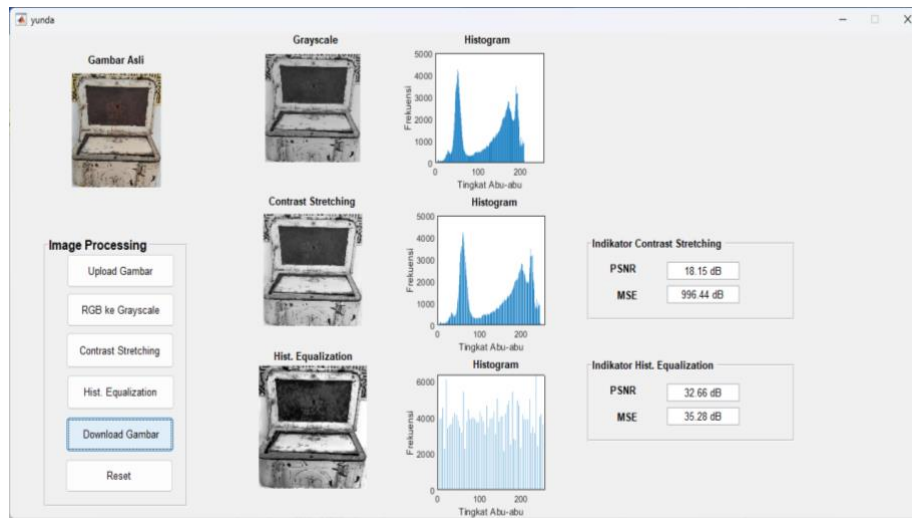


Figure 14. Test Results test_citra_8

This figure illustrate the result after processing the eighth test image which is test_citra_8. First of all, the contrast of image is low and it means it is hard to distinguish between the elements of image. The contrast stretching method improves on the binary range therefore making the images clearer and brighter. The histogram equalization process relieves the noise and smoothen the image by providing the even distribution between the pixel intensities of the image. The outcome though, is the general enhancement of the image quality which is made sharper, balanced and has improved details with regard to features and contrast ratios.

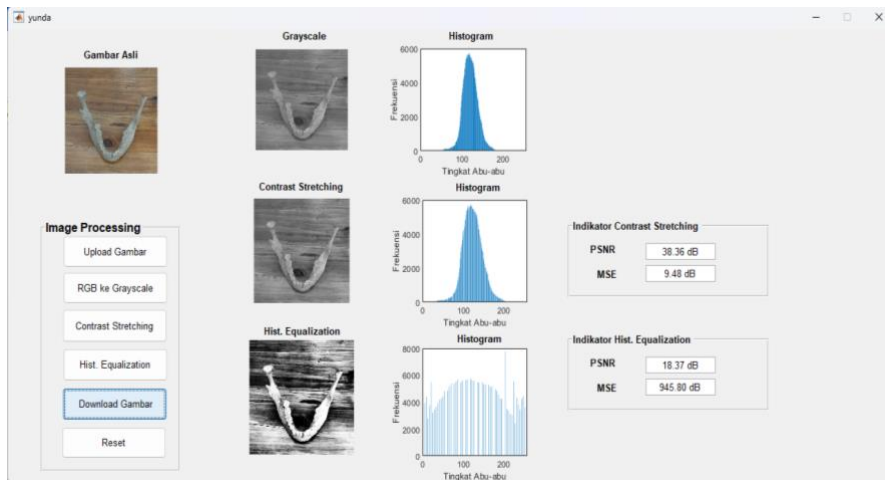


Figure 15. Test Results test_citra_9

In this figure, the ninth test image (test_citra_9) that has been applied with contrast stretching and histogram equalization. In the original image there exists low contrast, meaning the image contrasting intensities are low, so it is difficult to distinguish certain details of the image. The contrast stretching method tends to enhance the gray scale levels of the image and therefore, provides visibility of the image as clear as that of a bright light. It is followed by the histogram equalization to adjust pixel intensities and thus improve picture contrast and make previously hidden information visible. The last outcome, which comprises of both 12-bit and 14-bit versions of the photograph, is enhanced sharp edges, higher possibility of a balanced view and resolution for tonal differences.

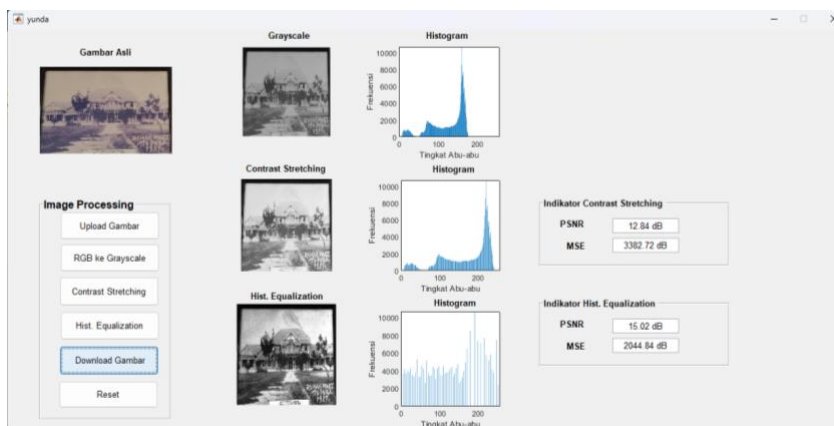







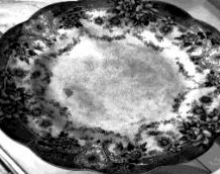












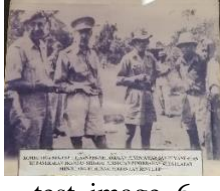









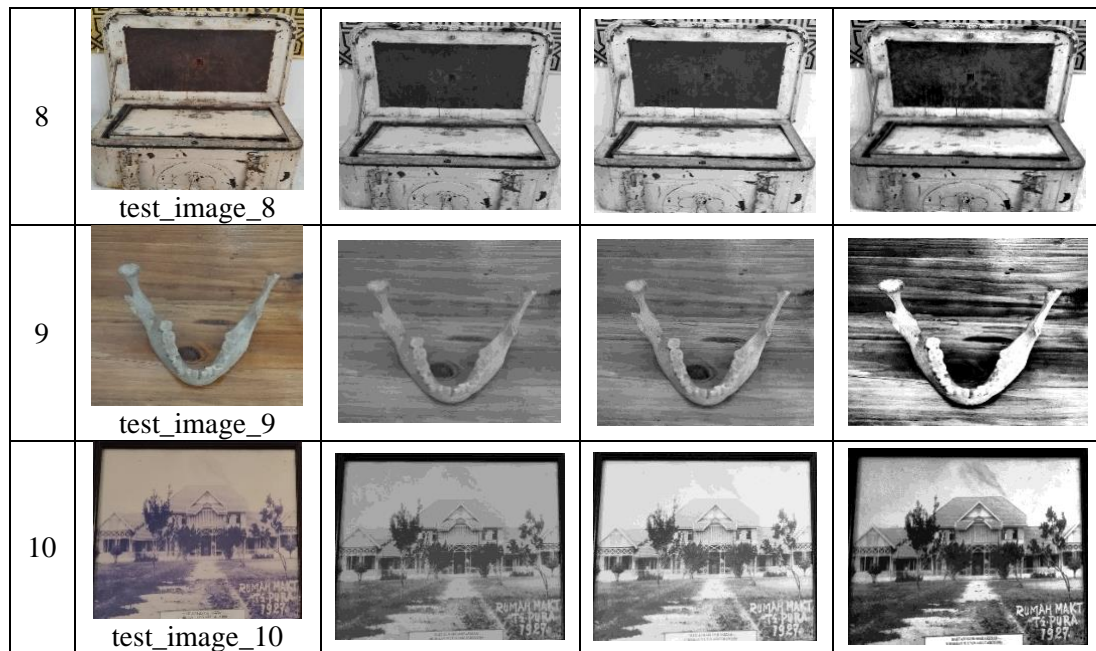
Figure 16. Test Results test_citra_10

The following figure shows the processed of tenth test image that have been tested (test_citra_10). In the original image, the contrast is low and in result does not provide satisfactory level of sharpness and clarity. The contrast stretching method is efficient in expanding the grayscale level range making the image more brighter and of enhanced contrast. The histogram equalization enhances the image by giving equal or similar number of pixels to all the intensity levels leading to clear image. These changes are most notable in places that were hitherto shrouded in low contrast and are now clearly defined.

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.

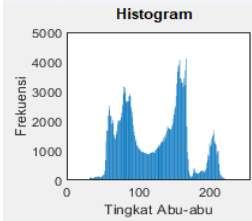
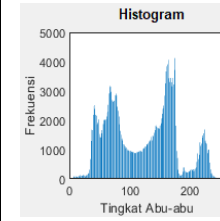
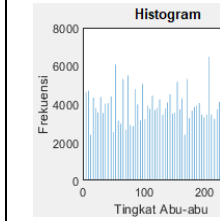
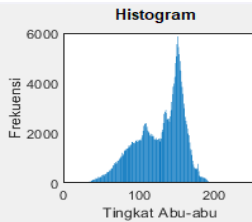
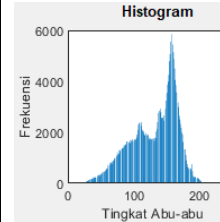
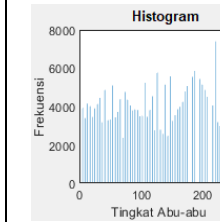
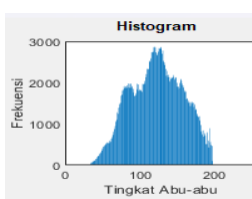
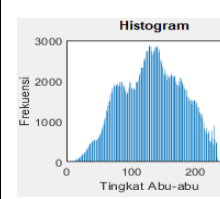
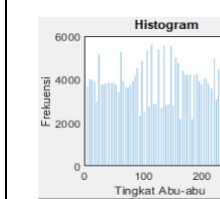
Table 8. Image Testing Results

No	Image File Name	Grayscale	CS	HE
1	 test_image_1			
2	 test_image_2			
3	 test_image_3			
4	 test_image_4			
5	 test_image_5			
6	 test_image_6			
7	 test_image_7			



Testing of all the images after application of grayscale conversion followed by contrast stretching and histogram equalization is shown below in the table: The constituents of the table include the image file names the processing methods under which they were processed. Nevertheless, entries here and there in each column are not specific, which implies that the information is summarized, stating the processes in improving the image. In this table, one can describe the actions performed and sort the test images based on the applied image processing procedures to make sure that all images have been subjected to a similar sequence of operations.

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			
3	test_image_3			

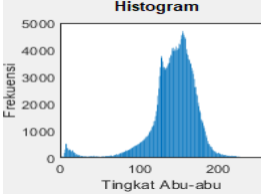
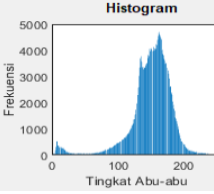
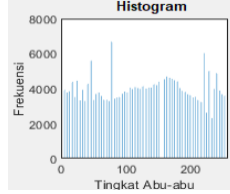
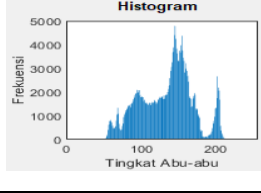
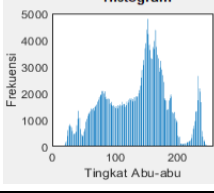
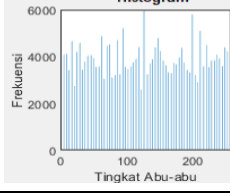
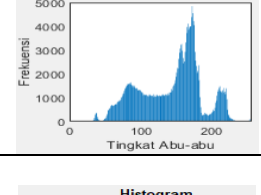
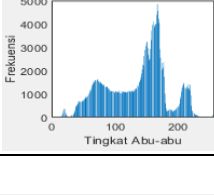
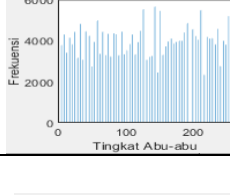
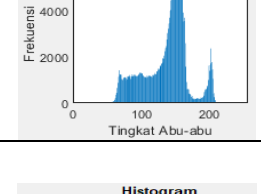
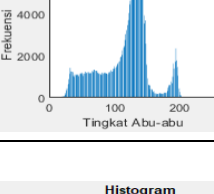
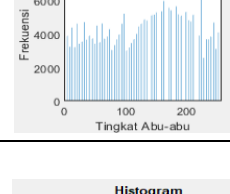
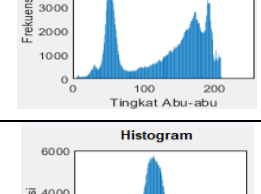
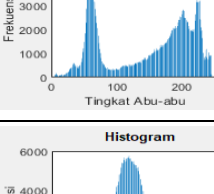
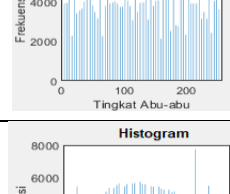
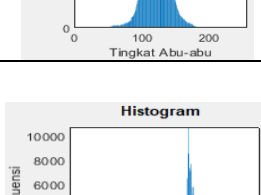
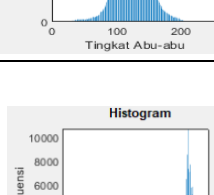
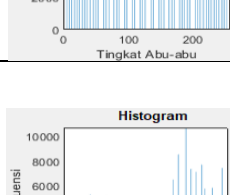
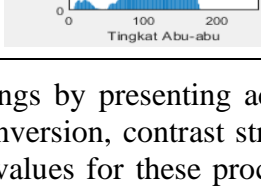
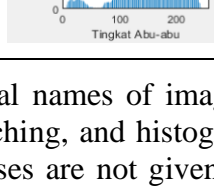
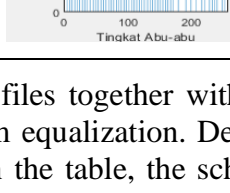
4	test_image_4			
5	test_image_5			
6	test_image_6			
7	test_image_7			
8	test_image_8			
9	test_image_9			
10	test_image_10			

Table 9 extends the findings by presenting actual names of image files together with the outcomes of grayscale conversion, contrast stretching, and histogram equalization. Despite the fact that the specific values for these processes are not given in the table, the scheme indicates the nature of the comparative consideration of the image modifications through these methods. This table is designed to show the movement of pixel intensity distribution and contrast of each image in the successive stages of processing and thereby emphasize the improvement that the employed methods can bring.

Table 10 PSNR 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

Table 10 presents the quantitative analysis of the image enhancement about PSNR and MSE for contrast stretching and histogram equalization are tabulated below. From the obtained PSNR values, it is clearly seen the degree of enhancement that have been obtained with the higher values meaning better image enhancement. The MSE values quantify the difference between the original and processed image and the lower the value is the fewer differences that exist. By comparing the images processed with the help of contrast stretching and histogram equalization for different images displayed in this table, it is possible to make a conclusion regarding the efficacy of one or the other method in achieving enhanced image quality and better match to the original image.

As described previously, contrast stretching achieved objective 1 of stretching the grayscale dynamic range effectively brightening and increasing the contrast of images and making previously masked details more apparent. This is in agreement with the general research on images, whereby improving contrast is known to enhance the patent and visibility of features in low contrast images as recognized in contrast stretching. Yet the adaptations were enhanced by the histogram equalization which worked to spread the pixel intensity values more evenly across the entire contrast of the picture. Experimental analysis of this technique has highlighted the method's capacity to improve global contrast by altering the intensity distribution, and thus, this technique is widely applied in different fields of image enhancement, for example, in applications proposed by (Yahaghi et al., 2024).

As such, the discoveries of this study would be beneficial to the field of digital heritage in particular because of the goal to retain the graphics in the original form and as legible as possible. Historical artefacts are very fragile in most cases and may have undergone some varying levels of deterioration and this means that they need to be repaired in order to provide access to researchers in the future (Hassan, 2020; Malik et al., 2021; Jones et al., 2020). In exploiting these two techniques, the purpose of this study is therefore to assert their usability in heritages after proving their ability in improving details of blurred images. This is in line with themes present in current digital heritage literature where more and more often, image processing is used for preservation and restoration of the artefacts (Ramadhan et al., 2023).

Digital image processing Field Heritage The methodological contribution of the study to the field and to the existing scholarly conversations regarding the topic is hence useful (Abgaz et al., 2021; Martinez et al 2021; Pietroni & Ferdani, 2021; Tejedor et al., 2022). The enhancement of historical artifact images by using the application of contrast stretching and histogram equalization is one way that has not been applied by many and is outside the traditional scope of their applicability (Aidilia & Sriani, 2024; Paul et al., 2022;

Vijayalakshmi & Nath, 2021; Ulutas & Ustubioglu, 2021). Earlier research has mainly centered on their use in different fields including medical imaging, night time imagery and image enhancement (Aidilia & Sriani, 2024). Through the successful implementation of these techniques in the current work for the classification of the historical pieces, the current research aims to fill the existing gap between the computer vision advances on image processing and their real world application in historical artifacts preservation (Brasington et al., 2021). Such interdisciplinary approach beneficial for both fields as it extends the arsenal of techniques used in conservation and opens new directions in image processing.

Also, the research helps to contribute to the discussions about the use of technology for preservation of heritage. For further details we can turn to the application of digital technologies as they are becoming more critical in documenting cultural heritage (Hou et al., 2022). The successful application of contrast stretching, and histogram equalization proved in this study strengthens the above argument that digital technologies hold potential to significantly reduce the impact of physical deterioration in cultural assets. This is especially important when it comes to the process of using technology to capture and share the results of the research and documentation of cultural properties where digital images are utilised as documentation and as a method for a subsequent study.

In addition to the current findings, this study has important implications which open several directions for further research and practical utilization. The first and probably the major weakness of this research is that the number of tested images was only 10. Despite the results, additional investigation could be conducted on a larger and more diverse set of images, and, thus, assess the feasibility of the techniques under investigation across different kinds of artifacts. Further research could also examine utilization of these approaches with additional advanced processing methods like the machine learning based enhancement algorithms. Developments of artificial neural network in the recent past have demonstrated feasibility of using machine learning in enhancing image quality and making image enhancement procedures more efficient and faster which can lead to further refinement of results achieved by very fundamental techniques like contrast stretching and histogram equalization (Yahaghi et al., 2024). Further research has to be done in order to explore how these enhancements are going to affect the analyses of the artifacts, their patterns or their historical context. Although the goal of this work was to investigate improvements in the perceived appearance of the image, it is necessary to minimize the impact of post-processing on the values and distort the results if necessary. Historical realism has to be maintained at all times, and any of the enhancement methods has to be proven so as not to alter the contents of this information, which is embedded in the images.

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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