Improvement of Hybrid Image Enhancement for Detection and Classification of Malaria Disease Types and Stages with Artificial Intelligence

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***Abstract*. Malaria is an infectious disease throughout the world where the disease is transmitted by infected female Anopheles mosquitoes. Malaria has some symptoms that are almost like ~~covid~~COVID-~~-~~19. Malaria has several other symptoms, characterized by chills, anemia, cold sweats, nausea and vomiting, and a sudden drop in blood pressure. Identification of the type of malaria begins with preprocessing, feature extraction, and classification for identification. Image improvement is part of the preprocessing stage to improve image quality so that the malaria parasite object in the image can be seen clearly. This study tries to improve the algorithm with hybrid dark and contrast stretching. Performance evaluation of malaria parasite image improvement using Mean Square Error (MSE) and Peak Signal Noise Ratio (PSNR). The results obtained with the improvement of dark hybrids and contrast stretching can improve the image quality of malaria parasite objects with MSE value = 0.0095 and PSNR value = 22.8404, compared with dark stretching, contrast stretching, histogram equalization.**

***Keywords*: Artificial Intelligence, Malaria, Dark Stretching, Contrast stretching, histogram equalization, and dark and contrast stretching.**

1. Introduction

Malaria is an infectious disease that occurs all over the world, especially in tropical climates. The Ministry of Health said that data on malaria cases is still difficult to eliminate because several regions have not succeeded in eliminating any of these malaria cases, such as in Papua, Maluku, and West Papua. Director of Prevention and Control of Vector and Zoonotic Diseases of the Ministry of Health Didik Budijianto explained that finding malaria cases is a challenge, especially during the COVID-19 pandemic[1]. Factors causing malaria are knowledge and attitudes of the community towards malaria. Infections caused by m~~M~~alaria can cause death, especially in high-risk groups such as pregnant women, infants, children under five. Malaria has symptoms that are almost like COVID-19 which are characterized by clinical symptoms, namely fever, chills, anemia, cold sweat, nausea and vomiting, and a sudden drop in blood pressure [1, 2]. Malaria is caused by the Plasmodium parasite and spread by a female Anopheles mosquito bite. Human Plasmodium falciparum, vivax, malaria, and oval [3].

Some standard tests are carried out by experts to identify malaria, using microscopic tools, ~~which~~ ant it takes ~~a~~ long time which require a laboratory to get the type of parasite and its stage. We need a system that can make it easy to identify the type of malaria parasite and its stage. Several stages will be carried out for image identification for the type of malaria, starting with the preprocessing stage, feature extraction, and classification for identification. The image improvement stage is part of the preprocessing stage where this stage is the main priority because if the malaria parasite image has good image quality, then for the next stage it can produce good results so that it will produce a high accuracy value.

Several studies using thick and thin blood smears for malaria detection have improved image quality. Sabir [4] using image brightness by increasing or decreasing a constant for each pixel in the image so that the histogram shifts in the application of the malaria parasite. Salamah [5] claims that e~~E~~nhancement of thick blood was achieved by contrast and edge correction. Contrast correction is accomplished by combining global and local contrast correction techniques, namely Dark Stretching and Contrast Limited Adaptive Histogram Equalization (CLAHE). While the edge correction algorithm employs Unsharp Masking Filtering (UMF) to smooth the edges of objects in microscopic images of malaria patients. Rakshit [6] used Sobel and Harris corner point detection to detect blood images with several forms of plasmodium, namely ring, trophozoite, merozoite, schizont. Khatkar [7] conducted biomedical image research using SIFT as well as D'Mayer and Coieflet wavelets to improve image quality. Hanif [8] used dark stretching on thick blood images, Nasir [9] used linear contrast stretching and modification of thin blood smears. According to Das [10], t~~T~~o increase the contrast of thick blood smears, illumination correction was performed using the red and blue channels by multiplying the intensity of each channel by the appropriate gain using a combination of gaussian low pass filtering, adaptive histogram equalization, and the h-minima transform. To improve the quality of thin blood smear images, this study uses a hybrid image improvement method that combines dark stretching and contrast stretching by increasing the value of the constant. MSE and PSNR values were used to evaluate the performance of a malaria parasite image improvement method. The greater the MSE value, the poorer the display on the resulting image. In contrast, the lower the MSE value, the better the display on the resulting image. The higher the PSNR value, the better the image display results obtained after image repair. The lower the PSNR value, on the other hand, the worse the results obtained in the image repair result. MSE and PSNR have an inverse relationship; the higher the PSNR value, the lower the MSE value [11].

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2. Research Methodology

This image quality improvement research uses several stages, where the malaria parasite image data obtained is primary data, originating from the Health Laboratory of North Sumatra Province and photographed using a digital microscope at the Health Polytechnic of North Sumatra. The image of the malaria parasite with four species, namely falciparum, vivax, malaria, and ovale, and for each species has four stages, namely ring, trophozoite, schizont, gametocyte. The image data infected with malaria amounted to 402 images consisting of 4 types of malaria parasites with 4 stages. The proposed system design can be seen in Figure 1.

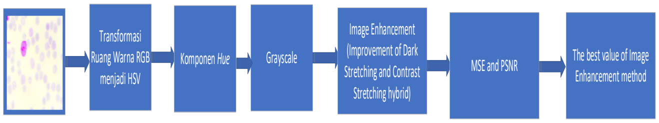

Figure 1. Design model for improvement malaria parasite image enhancement methods

Figure 1. This is a design model for developing a malaria parasite image enhancement method and few process.

2.1 Image data acquisition

At this stage, we present ~~is~~ the collection of malaria parasite image data. Starting with data on malaria parasite preparations sourced from the North Sumatra Provincial Health Laboratory, which was already contained in the preparations that had been given Giemsa staining. Furthermore, it is dripped with immersion oil, where the immersion oil serves to sharpen or clarify objects. Then the image is taken~~, where the image is taken~~ using a digital microscope with a magnification of 1000 times. The image can be seen on the monitor screen were in the image-taking process, accompanied by Health Laboratory officers to be able to find out the object, especially the type of malaria parasite. The types of malaria parasites used consisted of four types of malaria parasites namely vivax, ovale, falciparum, malaria and each type of malaria parasite had four stages, namely ring, trophozoite, schizont, gametocyte. Pictures of the types of malaria parasites and their stages can be seen in Figure 1.

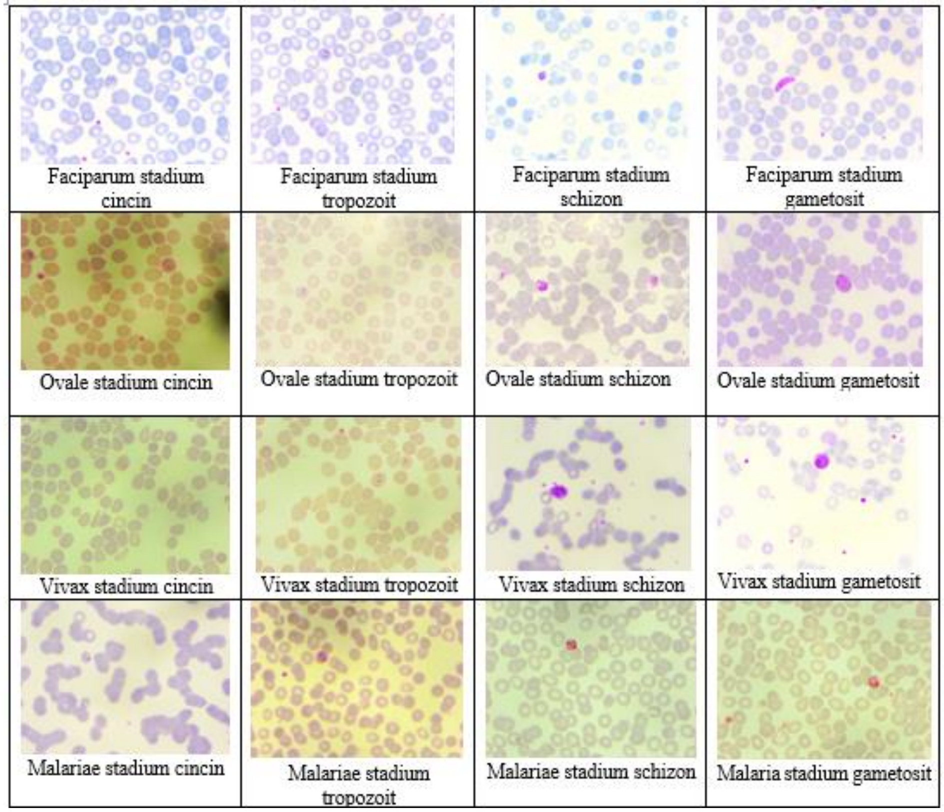
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Figure 2. Image of Malaria Parasites Falciparum, Ovale, Vivax, Malariae with four stages

Figure 2~~.~~ shows the image of malaria parasites falciparum, ovale, vivax, malaria with ring stage, trophozoites, schizonts, gametocytes. At the ring stage, it can be seen from its shape, which is ring-shaped and looks smooth and thin. This ring shape usually has one or two chromatin. There is usually no enlargement of the infected red blood cells but in ring-staged vivax malaria, the infected red blood cells are often larger than the infected red blood cells. In ovale malaria parasites, vacuoles are often seen.

The trophozoite stage, in the falciparum malaria parasite, does not appear to have changed shape, which is a ring-like shape but is thicker and denser. The amount of chromatin pigment may also increase and have a dense, amoeboid shape. There is a Schaffner point, the pigment tends to be smooth and brown. Infected red blood cells are usually larger than uninfected red blood cells. In this type of malaria parasite, malaria has a characteristic that is ribbon-shaped, chromatin is round and the cytoplasm is usually dense without vacuoles. The pigment is usually rough. In the malaria parasite ovale, the pink core is dilated and James's spots are seen in large numbers and rough.

At the schizont stage, the falciparum malaria parasite contains merozoites. In mature schizonts, it usually accounts for about 2/3 of the infected red blood cells. In schizont stage vivax malaria there are merozoites, each containing a chromatin dot. At this stage, the infected red blood cells become larger. The malaria parasite ~~malaria~~ contains merozoites, often arranged in irregular clusters. In the ovale malaria parasite, the nucleus is slightly larger and each nucleus is followed by the cytoplasm.

At the gametocyte stage, the falciparum malaria parasite is usually crescent-shaped. The cytoplasm is usually darker (female macrogametocytes), bluer, the cytoplasm of microgametocytes (male) is usually paler. ~~In~~ V~~v~~ivax malaria~~,~~ is usually spherical and fills the host cell. Infected red blood cells are usually larger than normal red blood cells. The cytoplasm is dark blue and contains brown pigment. Scuffner's point can be seen with proper staining. In malaria, there is no enlargement of infected red blood cells. The cytoplasm is blue and chromatin is red. In malaria, the ovale is round and sometimes looks like James bit.

2.2 RGB to HSV Color Space Transformation

After taking the malaria parasite image, the next step is to transform the HSV (Hue Saturation Value) color space, starting from converting the RGB (Red Green Blue) color space to HSV. Hue is the actual color, Saturation is the purity of the color, Value is the brightness of the color. The advantage of using the HSV color space is that several colors are the same as those captured by the human senses. HSV image formulation can be seen in equations 1 to 4 [12], [13].

$$H = \begin{cases} \theta & if\ B \leq G \\ 360\ \theta & if\ B > G \end{cases} \tag{1}$$

$$= cos^{-1}\left\{\frac{\frac{1}{2}[(\mathrm{R}-\mathrm{G})+(\mathrm{R}-\mathrm{B})]}{[(R-G)^2+(\mathrm{R}-\mathrm{B})\ (\mathrm{G}-\mathrm{B})]^{1/2}}\right\} \tag{2}$$

$$S = \begin{cases} 0 & if\ R = G + B \\ 1 - \frac{3}{(R+G+B)}[\min(R, G, B)] & other \end{cases} \tag{3}$$

$$V = \frac{1}{3}\ (R + G + B) \tag{4}$$

2.3 Transforming Hue component to Grayscale

Furthermore, the Hue component is converted to grayscale which will then be used to improve the image of the malaria parasite.

2.4 Image repair

In the image of the malaria parasite, there is still poor image quality, so here we use several image improvement methods to get an image that has good quality. Image improvement begins with calling the image from the grayscale image. This study analyzes the image improvement methods of histogram equalization, dark stretching, contrast stretching, and hybrid dark stretching with contrast stretching to get better image quality results.

Contrast stretching is part of the image improvement process that is point processing, meaning that this process depends on the intensity value of one pixel only, not on other pixels around it [14]. The contrast stretching function can be seen in Figure 2 [15].

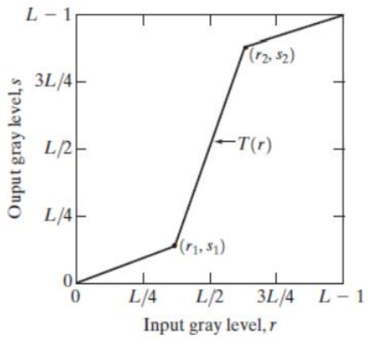

Figure 3. Contrast stretching function

In F~~f~~igure 3,~~.~~ ~~to~~ there is a change of the pixel contrast value from the original pixel, namely:

1. If the gray level is r1 r2 and s1 s2 the pixel contrast changes.
2. If r1=r2 and s1=s2, the pixel contrast does not change.
3. Image thresholding if r1 = r2 and s1 = 0 and s2 = 255.

Histogram equalization (HE) is a popular image improvement technique that can be used to flatten histograms. HE can provide a larger difference in pixels so that the information in the image can be captured by the eye. The HE technique is divided into two categories, namely the global histogram method and the local histogram method [16]. Histogram alignment is obtained by changing the gray degree of a pixel (r) with a new gray degree (s) with the transformation function T, namely s= T(r). The meaning is that r can be recovered from s by the inverse transformation r=T-1(s), where 0<=s<=1. The main target of histogram alignment is to obtain histogram equalization so that the degree of gray has a relatively equal number of pixels. The histogram alignment equation can be seen in equation 5 [17], [18].

$$p_r(r_k) = \frac{n_k}{n}\, dalam\ hal\ ini\ r_k = \frac{k}{L-1}\ , 0 \le k \le L-1, \tag{5}$$

w~~W~~here the gray degree (k) is normalized to the largest gray degree (L-1). The value of r_k = 0 represents black, and r_k = 1 represents white on a grayscale.

Dark Stretching is a technique that uses auto-scaling, a linear mapping function, to increase an image's brightness and contrast. The dark stretching technique uses the image's original brightness and contrast levels to adjust. Equations 6 and 7 show the dark and contrast stretching formulation [19], [20].

$$I'(a,b) = \begin{cases} \frac{I\,(a,b)}{Th}\, x\ new\ Th & ; for\ I(a,b) < Th \\ \left[\left(\frac{I\,(a,b)-Th}{255-Th}\, x\ (255 - new\ Th)\right)\right] + new\ Th & ; for\ I(a,b) > Th \end{cases} \tag{6}$$

$$I'(a,b) = \begin{cases} \frac{I\,(a,b)-Th}{255-Th}\, x\ new\ Th & ; for\ I(a,b) < Th \\ \left[\left(\frac{I\,(a,b)-Th}{255-Th}\, x\ (255 - new\ Th)\right)\right] & ; for\ I(a,b) > Th \end{cases} \tag{7}$$

The output and input pixel intensities are I'(a,b). The stretching factor is new Th. The dark stretching process tends to stretch values above the threshold. Figure 4 depicts dark and contrast stretching.

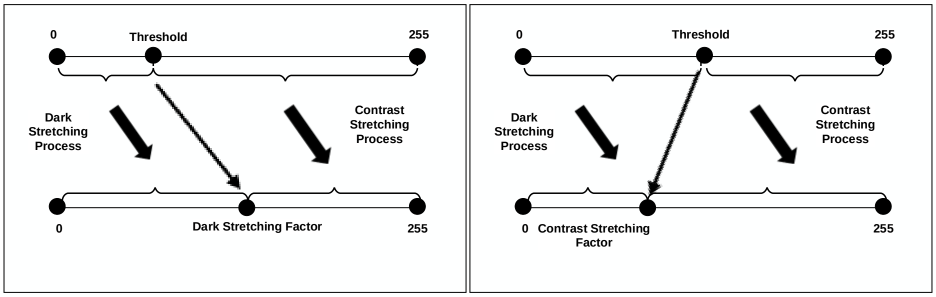

Figure 4. Dark Stretching dan Contrast Stretching Process

Figure 4 shows the hybrid process of dark and contrast stretching methods by providing a new threshold which is a stretching factor. The development which is a novelty in this research is the development of an image improvement method using a hybrid of dark and contrast stretching methods as well as algorithm improvement on dark and contrast stretching by increasing constant values. The development of a hybrid algorithm for the dark and contrast stretching methods can be seen in Figure 5.

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   Dark Stretching and Contrast Stretching Algorithm
1. Call the HSV color space transformed image : Hue
2. Determine the pixel intensity (dark stretching):
   Img_adj = imadjust(Img_Hue,[graythresh(Img_Hue) 1])
3. Determine the level of gray level spread and increasing a constant value
   (contrast stretching)
   Img_adj = 0.1 + imadjust(Img_adj);
4. Save as dark and contrast stretching image
5. Repeat Steps 1 to 5, for other images
6. Finish
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Figure 5. Improvement of Hybrid algorithm of dark and contrast stretching method

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2.5 Performance Evaluation

The MSE and Peak Signal to Noise Ratio are used to evaluate image improvement performance (PSNR). It is possible to measure the image quality improvement method by comparing the final image to the original image, but it is difficult to detect abnormalities in medical images without a solid knowledge base. The MSE is calculated by comparing the pixels of the original image to the resultant image at the same pixel position. The PSNR is the maximum strength of the image signal to noise, which affects the representation accuracy [21], [22]. Equations 8 and 9 show the two performance measures.

$$MSE = \frac{1}{AB}\sum_{x=1}^{A}\sum_{y=1}^{B}(g(x,y) - f(x,y)) \quad (8)$$

where $g(x,y)$ is the image before the image repair and $f(x,y)$ is the image after repair.

$$PSNR = 10log_{10}\left(\frac{(Max\ I^2)}{MSE}\right) \quad (9)$$

3. Results and Discussion

The parasite images used are 402 images of malaria parasites with four types of malaria parasites where each type of parasite consists of four stages with a size of 2592 x 1944 pixels. An example of HSV color results for malaria parasite images can be seen in Figure 6.

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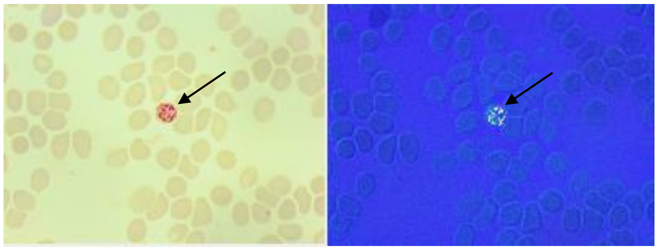
(a) (b)

Figure 6. Example of the color space transformation of the malaria parasite image (a) RGB image, (b) Image converted from RGB to HSV

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Figure 6(a)~~.~~ shows an RGB image, then it is converted to HSV (b). Transformation of RGB color space into HSV can be assumed coordinates R, G, B (0 or 1) which is a sequence of red, green, blue colors in the RGB color space, max is the maximum value of the value (red, green, blue), min is the value minimum of values (red, green, blue). After converting the color space to HSV, what is used in the next stage is the Hue component, because the three HSV components are visually able to distinguish between objects and the background is the hue component where the hue component is obtained from the HSV image.

Based on equation 1~~.~~ the results of the image of the malaria parasite transforming the HSV color space, namely the Hue component, can be seen in Figure 7.

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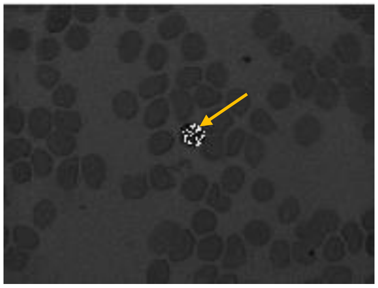

Figure 7. Example of the image of the malaria parasite transforming the HSV color space, namely the Hue component

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Figure 7~~.~~ is the result of the image of the malaria parasite transforming the HSV color space, namely the Hue component. In the picture, it can be seen that the parasite object has been distinguished from the background.

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Furthermore, the conversion to grayscale is carried out and after getting the results of the grayscale image, it is continued to make improvements using contrast stretching, histogram equalization, dark stretching, ~~and~~ hybrid dark stretching and contrast stretching methods. Examples of grayscale results and 4 image improvement methods can be seen in Figure 8.

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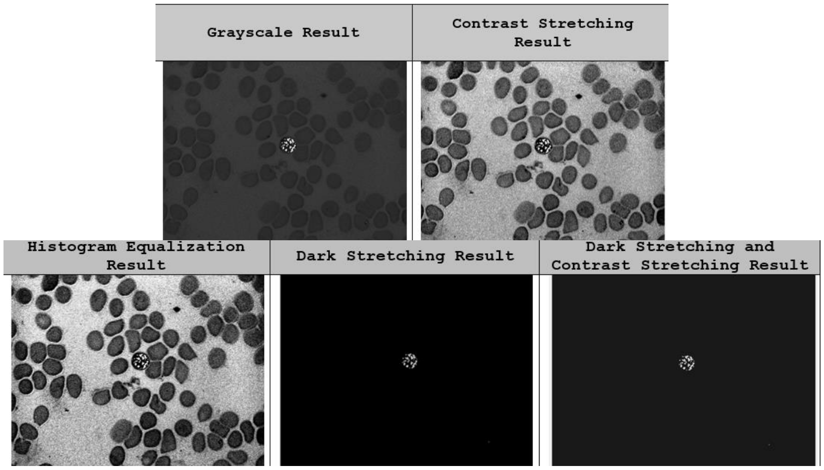

Figure 8. Example of conversion results to grayscale and 4 image improvement methods

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Figure 8~~.~~ shows a sample of the malaria parasite image converted to grayscale, from the grayscale image then image correction is carried out where the contrast stretching results can be seen to have more contrast than the grayscale results.~~,~~ T~~t~~he histogram equalization results show ~~can be seen~~ that the malaria parasite image has become more uniform, dark results stretching can be seen, the image increases the intensity of the image so that it distinguishes the object of the malaria parasite, as well as the results of hybrid dark stretching and contrast stretching.

The results of the four image improvement methods with 402 images were evaluated using MSE and PSNR. The results of the average MSE and PSNR values using contrast stretching, histogram equalization, dark stretching, and hybrid dark stretching and contrast stretching can be seen in Table 1.

Table 1. Average MSE and PSNR values for image repair using Contrast Stretching, Histogram Equalization, Dark Stretching, and hybrid Dark Stretching & Contrast Stretching

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Number of images	Contrast Stretching		Histogram Equalization		Dark Stretching		Dark Stretching andContrast Stretching	
	MSE Average	PSNR Average	MSE Average	PSNR Average	MSE Average	PSNR Average	MSE Average	PSNR Average
402	0.036158	30.6815	0.083256	12.3006	0.0265	16.0495	0.0095	22.8404

Table 1~~.~~ shows the average results of MSE and PSNR value using 402 images consisting of 4 types of malaria parasites namely falciparum, vivax, malaria, ovale with each having 4 stages, namely ring, trophozoite, schizont, and gametocyte. Based on Table 1, it can be seen that the results of a good image improvement method are hybrid dark stretching and contrast stretching, which have the smallest MSE value compared to dark stretching, contrast stretching, histogram equalization. Results are obtained using dark stretching and contrast stretching with MSE value = 0.0095 and PSNR value = 22.8404.

4. Conclusion

Based on the description of the previous sections, the conclusions that can be drawn are: ~~:~~

1. By using 4 methods ~~of~~ for improving the image of the malaria parasite, the development of a hybrid dark and contrast stretching method has a better image quality improvement.
2. The evaluation results show that using dark and contrast stretching is better with MSE = 0.0095 and PSNR = 22.8404, while using contrast stretching shows MSE = 0.036158 and PSNR = 30.6815, histogram equalization with MSE = 0.083256 and PSNR = 12.3006, dark stretching with MSE = 0.0265 and PSNR = 16.0495.

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In the concluding section, the next point explains the impact of evaluating the development of the hybrid dark and contrast stretching method

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