Color Image Enhancement of Acute Leukemia Cells in Blood Microscopic Image for Leukemia Detection Sample

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Abstract— **Leukemia is a type of cancer that affects the white blood cell. Early detection of leukemia is important to reduce the rate of mortality. In order to detect acute leukemia, conventional screening method based on microscopic image is used, where sample of blood cell will be taken from the suspected leukemia patient and manually white blood cell (WBC) condition is observed using microscope. The manual screening process is tedious, time consuming and usually prone to error due to low contrast between the nucleus and cytoplasm of WBCs. This report introduces a new enhancement method which is a combination of Particle swarm optimization (PSO) algorithm and contrast stretching, known as Hybrid PSO-Contrast stretching (HPSO-CS). The PSO has been used to optimize the fitness criterion in order to improve the contrast and detail in microscopic image by adapting the parameters as a contribution to enhancement technique. In this study, PSO algorithm is used to perform image segmentation to remove all the unwanted part such as red blood cell (RBC), platelet and also the background while retain the WBC part. The segmentation algorithm uses saturation S-component based on Hue, Saturation, Intensity (HSI) color model. After the segmentation is done, contrast stretching process is applied to the original image to stretch intensity of the pixel. Then the segmented image is combined with the resultant image that has been stretched to produce the enhanced image. The results of the proposed method are evaluated by using mean-square error (MSE), Peak-signal-to-noise-ratio (PSNR) and Absolute mean brightness error (AMBE). This proposed method is benchmarked by comparing against two image enhancement methods, global enhancement and Class Limited Adaptive Histogram Equalization (CLAHE). Based on the results, it can be concluded that quality of the enhanced image for the proposed method is much better with the lowest MSE (2067.651), AMBE (43.51827) and highest PSNR (14.98671) compared to the global and CLAHE method. The proposed method can improve the screening process and assist haematologist in leukemia screening and detection by improving the visual appearance of the WBC.**

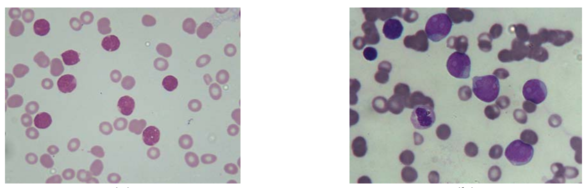
Keywords— leukemia disease; image enhancement; particle swarm optimization (PSO); contrast stretching

I. INTRODUCTION

Human body consist of most important part which is blood to keeps one alive. It carries oxygen for the whole body and others function. The blood can divided into three (3) main components which is red blood cell (RBC), white blood cell (WBC) and platelets [1, 2]. The functions of RBC is to carry oxygen and other materials to the tissue throughout the body, platelets help to form clots and WBC is to help fight off infections in the body. Insufficient amount of blood contain in human body could affect the metabolism greatly which could be dangerous if the fast treatment not taken [3]. Bone marrow is site where the lymphocytes and other blood are made. Bone marrow is a soft material present at the center of most of the bone.

Leukemia is a type of cancer that exist in human body [4]. Leukemia is a cancer of the early blood-forming and this disease is characterized by the uncontrolled growth of blood cells and usually involve the white blood cell (leukocytes) in the bone marrow. The abnormal of WBC produced by the bone marrow will occurs leukemia cancer. Leukemia cancer can be categorized into two (2) groups which is either chronic or acute types of leukemia. These types were grouped based on the disease develops and gets worst. For chronic leukemia usually get worst slowly and attack the adult. For acute leukemia, it usually gets worst quickly and usually happened in children.

For chronic leukemia, it will not be detected at primary stages because this type of leukemia may not affect the working of normal white blood cell in the primary stage and for this case patient will not be able to finding any types of symptoms. Basically, there are two types of chronic leukemia which is Chronic Lymphocytic Leukemia (CLL) and Chronic Myelogenous Leukemia (AML) [5]. For acute leukemia, in primary stage of leukemia, the cell cannot affect the normal working of white blood cell. But in the next stage, leukemia cell increase rapidly and uncontrolled. Commonly in acute leukemia also have two types of leukemia which is Acute Lymphocytic Leukemia (ALL) and Acute Myelogenous Leukemia (AML). Fig. 1 shows the sample of blood microscopic images with different types of leukemia.



(a) (b)

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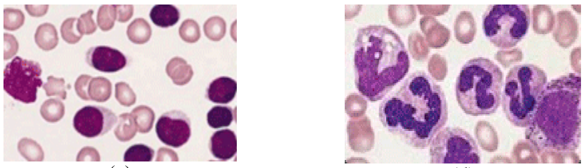

Fig. 1. (a) Acute Lymphocytic Leukemia (ALL). (b) Acute Myelogenous Leukemia (AML). (c) Chronic Lymphocytic Leukemia (CLL). (d) Chronic Myelogenous Leukemia (CML).

In order to recognise or detect the leukemia in WBC, the haematologist will do the analyzing process to determine the number of defected WBC in the blood sample. Usually in the diagnosis of leukemia, there are a few specific features that haematologist used by consider a shape and size of abnormal WBC to identify the type of leukemia whether it is AML or ALL. The complete blood count (CBC) is the underlying advance that should be considered for leukemia identification. The irregularities of the check will decide if the patient should do the bone marrow biopsy. For the analysis that has been finished by the haematologist physically, because of the human condition where individuals tend to commit error because of characteristic propensity such tiredness and administrator capacities, the outcome acquired can be corrupted.

Therefore, a computer-based image processing was introduced with a purpose of enhancement method to assist the haematologist in performing a quick analysis or as a second opinion for haematologist to make the decision. From the previous years, the image processing is a one of the important fields that has been used for detection of leukemia. Image processing usually used to perform the diagnosis of blood, X-ray, CT scan, MRI and many more in order to detect disease.

Gopal et al. [7] used the image processing for diagnosis of brain tumor through MRI. The method that has been used in image processing is clustering algorithms such as fuzzy c-means along with intelligent optimization techniques. The author used the median method to enhance the image and for the segmentation was done by using Fuzzy c-Means along metaheuristic algorithms such as PSO algorithm. As a result, the proposed method which is PSO was chosen for better performance, simple, reliable and efficient compared with Genetic algorithm.

Harun et al. [12] proposed an unsupervised segmentation technique for acute leukemia cells using clustering algorithm. In her study, three segmentation technique had been used and comparison has been made between them. The three method is k-means clustering, Fuzzy c-means and modification of k-means name as moving k-means. Segmentation was performed on three segmentation technique, and each has different performance. The moving k-means was chosen as highest classification accuracy.

In [13], Madhloom et al. proposed application of feature extraction, selection and cell classification to the recognition and differentiation of normal lymphocytes versus abnormal lymphoblast cells on the image of peripheral blood smears. Based on the research, the Otsu thresholding method was utilised. To get the effective segmentation, Linear Contrast Enhancement, and Histogram Equalization was applied and followed by image arithmetic operation that could eliminate blood components other than white blood cells effectively. Besides that, Joshi et al. [11] proposed a WBC segmentation and classification method using image processing in order to detect acute leukemia. The author's aim is to make fast, accurate and automatic identification of different blood cell. This paper was proposed Otsu's threshold method for blood cell segmentation along with image enhancement and arithmetic for WBC segmentation.

Even though the image processing are widely used in medical applications, to the best of author's knowledge, there is no research on the enhancement for leukemia image. Therefore, new method for leukemia image enhancement is proposed in this study. The main target in this project is to improve visual appearance of WBC using image enhancement method for assisting haematologist in screening and diagnosing leukemia disease. The proposed method used in this project is the combination of PSO and the contrast stretching, called Hybrid PSO-Contrast Stretching (HPSO-CS). To evaluate the performance and the quality of image, the proposed method was compared with two enhancement method are selected such as global and CLAHE.

II. METHODOLOGY

This section explained about the methodology of the purposed method for the enhancement on leukemia images. Fig. 2 shows the process of enhancement that were applied in this study. In general, the method starts by importing the original images which is sample of blood microscopic images into the program. For the proposed method called HPSO-CS, there are three (3) stages that will be conducted before achieved the output of enhanced image. First the original image was converted from the RGB to the HIS color model conversion. From the HSI color model, the saturation which is S-component are taken to apply in the segmentation task. The PSO algorithm has been used for the segmentation part. Finally, contrast stretching is applied to PSO segmentation image. This proposed method will be compared with another two enhancement methods which is global and CLAHE. The detail about this enhancement process will be explained in the following sections.

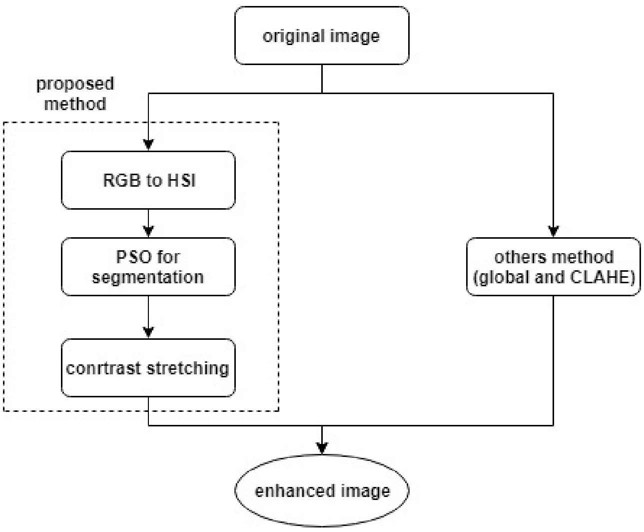

Fig. 2. The proposed method of enhancement for leukemia image.

A. Image Acquisition

Forty samples of blood image are been used in this project. These samples were provided by the Department of Hematology, Hospital Universiti Sains Malaysia (HUSM) Kubang Kerian, Kelantan. Leica microscope is an equipment that were involved during the process to take the sample of blood slide acute leukemia. The samples of blood slide images were captured and save into bitmap file (.bmp) with the resolution 800x600 using the Digital Infinity 2 camera.

B. Color Conversion RGB to HSI

The original colour image consists of three layer which is Red, Green and Blue. RGB is describe as combination with the primary colors, whereas, HSI describe color using more familiar comparisons such as color, vibrancy and brightness or intensity. The Hue also called H-component can be describe as the impression that refer to the dominant wavelength of the color stimulus. For Saturation S-component it refers to the required degree of white light to be added to pure color. Last for the I part is Intensity which means the brightness of the image. It has previously been reported in [21] that the *S*-component is the most dominant colour component for WBC segmentation. The RBC and unwanted background become less saturated in the S-component image and the segmentation process can be done accurately. Therefore, in this study, the S-component was selected as input information for image segmentation.

The RGB to HSI colour model conversion is obtained using the following equations [21]:

$$\mathrm{Hue} = \frac{\cos^{-1}(0.5\times((\mathrm{R-G})+(\mathrm{R-B})))}{((\mathrm{R-G})^2+((\mathrm{R-B})\times(\mathrm{G-B}))^{0.5})} \quad (1)$$

$$\mathrm{Sat} = 1 - \frac{3}{(R+\mathrm{G}+\mathrm{B})}\min(R,G,B) \quad (2)$$

$$\mathrm{Int} = \frac{1}{3(R+\mathrm{G}+\mathrm{B})} \quad (3)$$

where R, G and B represent the red, green and blue part of the RGB color model, respectively.

C. Particle Swarm Optimization (PSO)

The study proposed to integrate PSO with image segmentation algorithm prior to enhancement of blood images. PSO method was introduced by Eberhart and Kennedy in 1995 [15, 16]. PSO is an optimization that was inspired by social behaviour of bird flocking or fish schooling. The concept of PSO is every particle will fly through search space to find the best solution. Each particle will find the optimal globally by updating their position and velocity.

In this study, the PSO starts after completion of colour RGB to HSI conversion process. The S-component from the HSI color model is used in PSO to do the segmentation process. PSO will remove the all part such as RBC and other unwanted part from the image. At the end, the image of segmentation will leave only the WBC.

The procedure for segmentation using PSO is given as follows:

1. Initialize each particle to N_c randomly selected cluster centroid.
2. For t = 1 to the number of iterations,
    a) For each particle i
    b) For each data vector z_p
        i. Calculate the Euclidean distance $d(z_p, m_{ij})$ to all cluster centroids Cij using Equation 4.

$$d(z_p, m_j) = \sqrt{\sum_{k=1}^{N_d}(z_{pk} - m_{jk})^2} \quad (4)$$

where d is the distance of the centroid. Z_p denotes the p-th data vector, m_j denotes the centroid vector of cluster j and N_d denotes the input dimension.

        ii. Assign z_p to cluster C_{ij} such that $d(z_p, m_{ij}) = \min_{vc=1,\ldots,Ne}$ [17].
        iii. Calculate the fitness using Equation 5.

$$J_e = \frac{\sum_{j=1}^{Nc}[\sum \forall Z_p \in C_{ij} d(z_p, m_j)/|C_{ij}|]}{N_c} \quad (5)$$

where N_c is the number of centroids, d is defined in Equation 4 and $|C_{ij}|$ is the number of data vectors belonging to the cluster C_{ij}.

    a) Update the global best and local best position using Equation 6.

$$Y_{id} = \begin{cases} Y_{id} & if \quad f(X_i) \geq f(Y_i) \\ X_{id} & if \quad f(X_i) < f(Y_i) \end{cases} \quad (6)$$

where Y_i demotes the personal best position of the particle and X_i is the current position of the particle.

    b) Update the cluster centroids using Equation 7 and 8.

$$\mathrm{V_{id}} = \mathrm{WV_{id}} + \mathrm{C_1R_1(P_{id} - X_{id})} + \mathrm{C_2R_2(P_{gd} - X_{gd})} \quad (7)$$

$$\mathrm{X_{id}} = \mathrm{X_{id}} + \mathrm{V_{id}} \quad (8)$$

From Equations 7 and 8, V_i represents the velocity of the particles i, X_i indicates the position of particle i, W is the inertia weight, C_1 is the cognition factor, C_2 is the social factor, R_1 and R_2 are uniformly distributed random numbers between 0 and 1, Pi is the pbest and Pg is the gbest. Repeat steps (a) to (d) until the iteration reaches 100.

In this study the values of W, C_1 and C_2 are set to 0.72, 1.49 and 1.49 respectively. These values are found to be suitable for many applications.

D. Contrast Stretching

The final part of the proposed method is the contrast stretching process. In this part, the intensity of the original image will be stretch to fill the dynamic range of the image. Basically, for contrast stretching, it is used to prevent the excessive of light during shooting by extending the distribution of pixel-gray value. For this color image, there consist of three-layer image which is R, G and B that need to be stretch. Every layer will be stretched according to the value of maximum and minimum bound that obtained from segmentation image. For the minimum threshold value, it will be stretched to 0 and maximum value threshold will be stretched to 255.

E. Performance Evaluation

The quantitative enhancement of blood cell images are analysed by calculating three (3) measures as follows:

i) Mean-squared-error (MSE)

MSE is the one of the performance evaluations that usually is used to measure the quality of image. MSE is the average of the square of the difference between the enhanced and original image. The lower the value of the MSE, the better the method

$$MSE = \frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}\begin{bmatrix}\left(r(i,j)-r''(i,j)\right)^2 + \\ \left(g(i,j)-g''(i,j)\right)^2 + \\ \left(b(i,j)-b''(i,j)\right)^2\end{bmatrix} \quad (9)$$

ii) Peak-signal-to-noise-ratio (PSNR)

PSNR are used to measure the quality of the reconstructed image. The unit for the PSNR measurement is in decibels (dB). For the PSNR analysis, the higher PSNR value the better reconstruct image was produced. The formula to calculate the PSNR value as given as follows:

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

where R is set to 255 for an 8-bit image.

iii) Absolute mean brightness error (AMBE)

The difference between the mean intensity level of enhanced image with the mean intensity level of original image. The formula is given as:

$$AMBE = \left|I(y) - I(x)\right| \quad (11)$$

where I (y) is the mean intensity level of enhanced image and I (x) is the mean intensity level of original image. Low AMBE value indicate a better preservation of the method.

I. Results And Discussion

After the enhancement method is done, all the resulted image will be evaluated quantitatively using with a several performance evaluations which is. For the quantitative analysis, the performance of the system was evaluate using MSE, PSNR and AMBE. This evaluation is to determine the quality of the enhanced image by using proposed method with other method. All three results of enhancement image are shown in each of the Fig. 3-6 below. In each of the figure, consist of (a) represent as original image, while (b), (c) and (d) is the enhancement method. Besides, the results of analysis performance are shown in Table I.

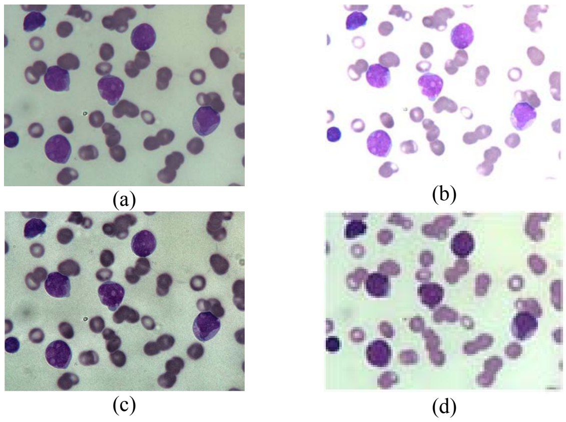

Fig. 3. AML 1 image. (a) Original image. (b) Global enhancement image. (c) CLAHE enhancement image. (d) Proposed enhancement image.

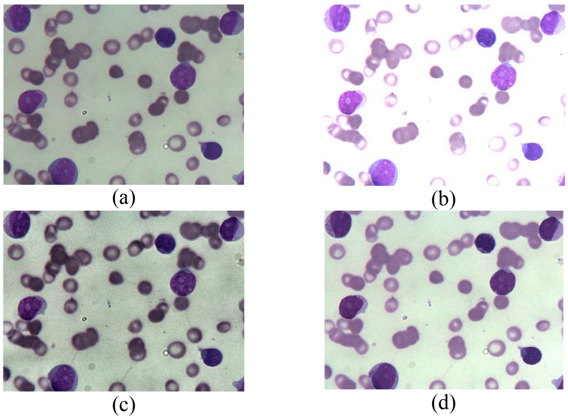

Fig. 4. AML 2 image (a) Original image. (b) Global enhancement image. (c) CLAHE enhancement image. (d) Proposed enhancement image.

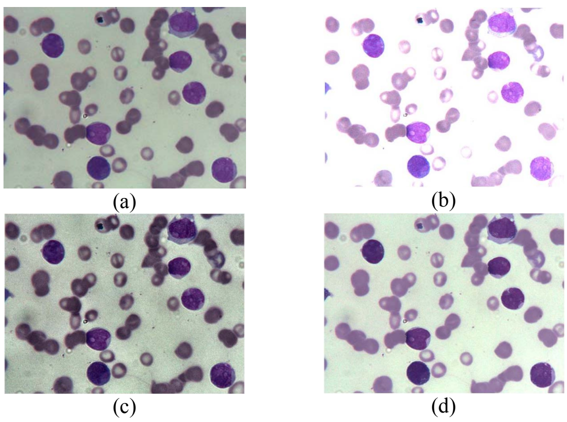

Fig. 5. AML 3 image. (a) Original image. (b) Global enhancement image. (c) CLAHE enhancement image. (d) Proposed enhancement image.

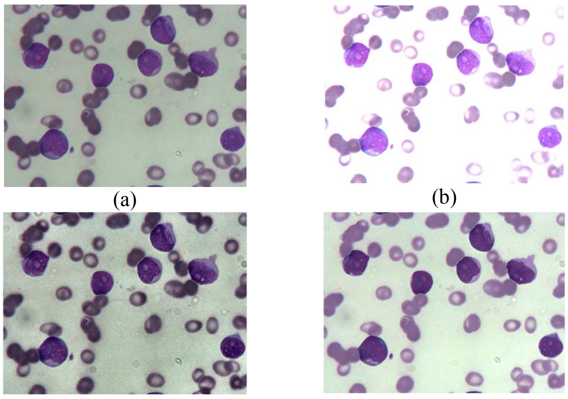

Fig. 6. AML 4 image. (a) Original image. (b) Global enhancement image. (c) CLAHE enhancement image. (d) Proposed enhancement image.

Table I & II shows the quantitative analysis of HPSO-CS, global enhancement and CLAHE method. Four AML images (Table I) and ALL images (Table II) has been evaluated their performance are measured by using MSE, PSNR and AMBE.

TABLE I. RESULT FOR MSE, PSNR AND AMBE FOR PROPOSED, GLOBAL AND CLAHE METHOD FOR AML IMAGE ENHANCEMENT

Image No.	Enhancement method	MSE	PSNR	AMBE
AML 1	Global	7436.43	9.42	84.62
	CLAHE	24674.71	4.21	152.40
	HPSO-CS	**2075.43**	**14.96**	**43.81**
AML 2	Global	7627.29	9.31	85.62
	CLAHE	24700.91	4.20	152.75
	HPSO-CS	**2022.44**	**15.07**	**43.17**
AML 3	Global	7577.86	9.34	85.31
	CLAHE	24732.48	4.20	152.76
	HPSO-CS	**2033.09**	**15.05**	**43.31**
AML 4	Global	7640.08	9.30	85.73
	CLAHE	24321.57	4.27	151.32
	HPSO-CS	**1979.06**	**15.17**	**42.47**

TABLE II. RESULT FOR MSE, PSNR AND AMBE FOR PROPOSED, GLOBAL AND CLAHE METHOD FOR ALL IMAGE ENHANCEMENT

Image No.	Enhancement method	MSE	PSNR	AMBE
ALL 1	Global	6452.99	10.03	78.57
	CLAHE	30710.32	3.26	173.96
	HybricPSO-Contrast stretching	**2339.02**	**14.44**	**47.58**
ALL 2	Global	6599.77	9.94	79.35
	CLAHE	30370.22	3.31	172.83
	HPSO-CS	**2288.54**	**14.54**	**46.80**
ALL 3	Global	6036.10	10.32	75.82
	CLAHE	31616.27	3.13	176.42
	HPSO-CS	**2497.74**	**14.16**	**49.20**
ALL 4	Global	6662.71	9.89	79.46
	CLAHE	30240.98	3.13	172.18
	HPSO-CS	**2264.05**	**14.58**	**46.51**

For the AML 1, the MSE value for global, CLAHE and proposed method is 7436.43, 24674.71 and 2075.43. These results show that the proposed method has the lowest value of MSE compared to others. For the PSNR evaluation test, the value for proposed method, global and CLAHE is 14.96, 9.42 and 4.21. In the PSNR analysis, the higher value, the method is best. So proposed method is the best method with the higher value of PSNR. Next for AMBE analysis, the data result has been calculated and shown in Table I. The value for proposed method, global and CLAHE is 43.81, 84.62 and 152.40. For the AMBE test, the lower value is much better the quality of the enhanced image.

Enhancement for ALL image is shown in the tabulated data in Table II. For ALL1 image, proposed method shows the best performance for the image enhancement compared with other two enhancement method. Overall, the proposed method produced a result with lower MSE, AMBE value and higher PSNR value. Therefore, the value for proposed method seen lower than the other enhancement techniques.

Table III presents the quantitative analysis of 30 samples using the three images enhancement methods. In this analysis, 30 samples of acute myelogenous leukemia images have been evaluated and the average of MSE, PSNR and AMBE are calculated. The result proved that the quality of image produced by the proposed method is superior against the global enhancement and CLAHE.

TABLE III. RESULT FOR AVERAGE MSE, PSNR AND AMBE OF 30 SAMPLES OF AML USING THE PROPOSED METHOD, GLOBAL AND CLAHE METHOD

Method enhancement	Average MSE	Average PSNR	Average AMBE
Global	7784.84	9.22	86.67
CLAHE	24491.53	4.24	152.35
HPSO-CS	**2067.65**	**14.99**	**43.52**

Table IV below shows the quantitative analysis of 10 samples of ALL using the three image enhancement methods. In this analysis, 10 samples of acute lymphocyte leukemia images have been evaluated and the average of MSE, PSNR and AMBE are calculated. The results proved that the quality of image produced by the proposed method is superior to the global enhancement and CLAHE.

TABLE IV. RESULT FOR AVERAGE MSE, PSNR AND AMBE OF 30 SAMPLES OF ALL USING THE PROPOSED METHOD, GLOBAL AND CLAHE METHOD

Method enhancement	Average MSE	Average PSNR	Average AMBE
Global	6490.54	10.01	78.58
CLAHE	30682.86	3.27	173.49
HybricPSO-Contrast stretching	**2327.98**	**14.46**	**47.14**

II. CONCLUSIONS

In this paper, a new method approach for the enhancement of leukemia image. This study proposed aim to assist haematologist to make the detection on the blood image in way to detect the presence of leukemia. This paper was introduced the new combination between PSO and contrast stretching. The output of proposed method was compared with another two enhancement methods which is global and CLAHE. The performance of output image between these three methods was evaluated by calculating the MSE, PSNR and AMBE value as shown in the result part. Based on the result, it can be concluded that the quality of the enhanced image for the proposed method is much better with the lowest MSE, AMBE and highest PSNR compared to the global and CLAHE method.

As a future, this research can be improved for a complete application which means it can make the classification and detection of leukemia such as the haematologist only enter the blood image and produce data result on a single mouse click.

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