Implementation of High Dynamic Range Rendering on Acute Leukemia Slide Images using Contrast Stretching

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***Abstract*— Acute leukemia is one of the critical disease that requires immediate treatment due to the rapid progression and accumulation of the cancerous cells. In recent years, image processing techniques had been explored to enhance the diagnosis of acute leukemia. However, microscopic image captured from the light microscope usually has poor quality due to the capability of the camera and improper operation by human operator. High Dynamic Range (HDR) imaging technique has been explored to solve the problem by increasing the dynamic range of the images captured. This paper presents a HDR rendering technique by using contrast stretching technique to enhance the morphological features of blast cells. The technique called Partial contrast stretching had been used to render HDR image. The results showed that the proposed method had enhanced the overall contrast and morphological features of the blast cells in the acute leukemia slide images.**

Keywords—Acute Leukemia, High Dynamic Range Imaging, Constrast Stretching, Image Processing, Microscopic Image

I. INTRODUCTION

Leukemia is one of the most common type of cancer in the general population and the most common childhood cancer in Malaysia. According to National Cancer Registry Report of Malaysia 2007, there are 50% of patients diagnosed in stage 3 and stage 4 [1]. Acute leukemia is one of the common type of leukemia, which may cause death due to the rapid progression and accumulation of the cancerous cells and it can be divided into two main types which are Acute Myelogenous Leukemia (AML) and Acute Lymphoblastic Leukemia (ALL) [2].

Over recent years, image processing techniques had been widely explored to ease the diagnosis task of acute leukemia. However, acute leukemia slide images captured by the camera usually have poor quality due to the limited capability of the camera and also improper operation by human operator. High dynamic range (HDR) imaging is one of the image processing technique that had been explored to overcome the poor quality of microscopic images, including acute leukemia slide images [3][4]. HDR technique is usually implemented by combining information from multiple images that are taken under different exposures. The drawback of this method is the camera need to be in stable condition and any vibration or shaking occurs during the capturing process will causes the slide image to became blurry [5]. Besides that, this method is not applicable for the previously captured acute leukemia slide images.

This paper proposed a HDR rendering technique by using contrast stretching technique to be applied on the previously captured acute leukemia slide images. This technique is able to enhance the morphological features of blast cells, such as Auer rods, and improves the overall contrast as well as the dynamic range of the images. The original image will be enhanced by using partial contrast stretching and the enhanced images will be further processed with HDR and tone mapping algorithm to generate an HDR image. The resulting HDR images is evaluated by comparing the dynamic range between the HDR images with the original images based on intensity histogram.

II. METHODOLOGY

A. Implementation Steps

In the diagnosis process of acute leukemia, the morphological features in the blast cells such as size and shape as well as the presence of Auer rod and nucleoli are very important parameters [4]. Thus, image enhancement is an important preprocessing step to enhance the quality of the acute leukemia slide image to ease the diagnosis process [6]. The goal of this proposed technique is to enhance the important features in the previously captured acute leukemia slide images by using contrast stretching technique and the HDR technique. The proposed technique consists of several implementation steps:

Step 1: Capture the slide images.

Step 2: Obtain the threshold value from the intensity histogram of the original image.

Step 3: Apply partial contrast stretching technique to the images by implementing the threshold and stretching value.

Step 4: Combine the enhanced images by implementing HDR technique then implementing tone mapping on the HDR image for displaying purpose.

B. Contrast Stretching Techniques

Contrast stretching technique is one of the image enhancement techniques that is widely explored to overcome the poor contrast issue on acute leukemia slide images [6][7][8][9]. Partial Contrast Stretching is an image enhancement technique that uses linear mapping function to enhance the contrast level and the brightness level of the image. The linear mapping function of partial contrast is as Equation 1[10]:

$$P_k = \frac{(max - min)}{(f_{max} - f_{min})}(q_k - f_{min}) + min \tag{1}$$

where,

P_k : Color level of the output pixel

q_k : Color level of the input pixel

f_{max} : Maximum color level of the input image

f_{min} : Minimum color level of the input image

max : Desired maximum color level of the input image

min : Desired minimum color level of the input image

Before the mapping process begin, it is necessary to determine the range of where the majority of the input pixels converge for each RGB color space. Thus, the average value for the RGB will be calculated to obtain the upper and lower threshold values by using the Equation 2 and Equation 3 respectively [8]:

$$maxTH = (maxRed + maxBlue + maxGreen)/3 \tag{2}$$

$$minTH = (minRed + minBlue + minGreen)/3 \tag{3}$$

where $maxRed$, $maxBlue$ and $maxGreen$ are the maximum color level for each red, green and blue color palette respectively, whereas $minRed$, $minGreen$ and $minBlue$ are the minimum color value for each red, green and blue color palette respectively. $maxTH$ and $minTH$ are the average value of the maximum and minimum color levels for the RGB color space and will be used as the desired color level for red, green and blue color. The linear mapping function in Equation 1 will be used for the pixels transformation as shown in Equation 4 [8].

$$out(x,y) = \begin{cases} \dfrac{in(x,y)}{minTH} * NminTH & \text{for } in(x,y) \le minTH \\ \left[\dfrac{(NmaxTH - NminTH)}{maxTH - minTH} * (in(x,y) - minTH)\right] + NminTH & \text{for } minTH < in(x,y) < maxTH \\ \left[\dfrac{in(x,y) - maxTH}{255 - maxTH} * (255 - NmaxTH)\right] + NmaxTH & \text{for } in(x,y) \ge maxTH \end{cases} \tag{4}$$

where,

$in(x, y)$: Color level of the output pixel

$out(x, y)$: Color level of the input pixel

$maxTH$: Lower threshold value

$minTH$: Upper threshold value

$NmaxTH$: New lower stretching value

$NminTH$: New upper stretching value

The pixels within the range of $maxTH$ and $minTH$ will be stretched to the desired range of $NmaxTH$ and $NminTH$ whereas the remaining pixels will be compressed according to the Equation 4. The stretching and compression processes will enhance the overall contrast of the image as the pixels of the image will be mapped to a wider range and brighter intensity level. In this proposed technique, the partial contrast stretching is applied in three different approaches, according to the technique proposed in [8]. Figure 1, 2 and 3 illustrate the proposed approaches.

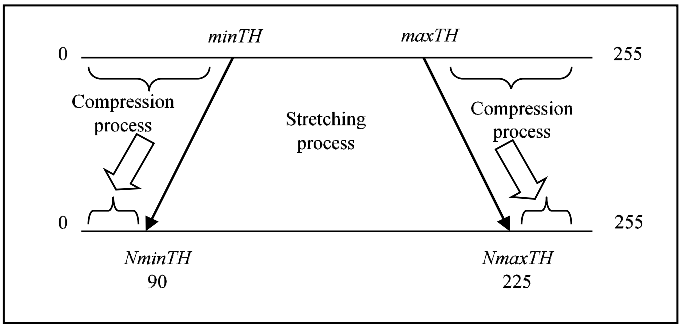

Fig. 1. Process of Partial contrast stretching with approach 1.

As shown in Figure 1, the color level between $minTH$ and $maxTH$ that obtained from Equation 4 are stretched to the $NminTH$ and $NmaxTH$ values of 90 and 225 respectively. The color level below the $minTH$ will be compressed to the range of 0 to 90 and the color level above the $maxTH$ will be compressed to the range of 225 to 255 [8].

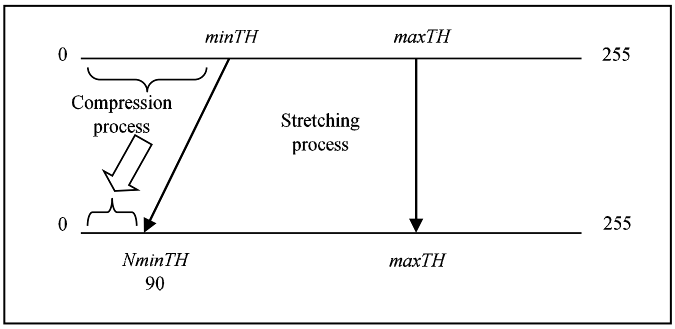

Fig. 2. Process of Partial contrast stretching with approach 2.

For approach 2, the technique proposed in [8] is modified, the *maxTH* value will be maintained while the *minTH* will be stretched to the *NminTH* value of 90 as shown in Figure 2. The color level below the *minTH* will be compressed to the range of 0 to 90, whereas the color level above the *maxTH* will be maintained its value.

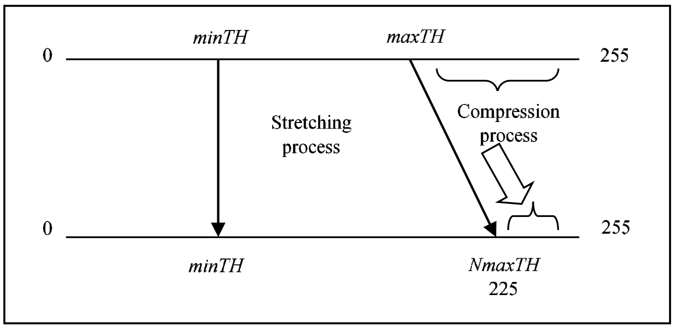

Fig. 3. Process of Partial contrast stretching with approach 3.

Likewise for approach 3, the *minTH* value will be maintained while the *maxTH* will be stretched to the *NmaxTH* value of 225 as shown in Figure 3. The color level above the *maxTH* will be compressed to the range of 225 to 255, whereas the color level above the *minTH* will be maintained its value. After that, the images obtained from the three approaches will be further processed to form an HDR image by using proposed HDR algorithm.

C. High Dynamic Range Imaging

In photography, dynamic range refers to the ratio between the maximum and minimum intensity values present in the image. The dynamic range in real-world scenes could be extremely wide and most of the cameras are not able to capture it due to the limited dynamic range of the camera sensor. Similar condition also exists in the acquired acute leukemia slide images. Thus, HDR technique has been explored to enhance the dynamic range, contrast as well as the morphological features of acute leukemia slide images [4].

The proposed technique applied Debec and Malik's algorithm [11] to construct high dynamic range radiance maps by merging the enhanced acute leukemia slide images with three different approaches of partial contrast stretching. The radiance mapping function can be expressed as Equation 5.

$$O = \sum_{i=1}^{N} \sum_{j=1}^{P} \left\{ w(Z_{ij}) \left[g(Z_{ij}) - \ln E_i - \ln \Delta t_j \right] \right\}^2 + \lambda \sum_{z=Z_{\min}+1}^{Z_{\max}-1} \left[w(z) g''(z) \right]^2 \quad (5)$$

where,

i : Spatial index over pixels

j : Indexes over exposure time Δt_j

N : Number of pixel location

P : Number of photographs

$g(Z_{ij})$: Logarithm exposure corresponding to pixel value Z

Z_{min} and Z_{max} : Pixel value boundaries

Z_{ij} : Pixel recorded at position i and exposure j

E_i : Film irradiance value at image position i

Whereas $g''(z)$ is the second derivative of g as expressed in Equation 6 and λ is the scalar quantity that weights the smoothness term relative to the data fitting term. The weighting function $w(Z_{ij})$ can be expressed as Equation 7 [11].

$$g''(z) = g(z-1) - 2g(z) + g(z+1) \quad (6)$$

$$w(z) = \begin{cases} z - Z_{min} & for\ z \le \frac{1}{2}(Z_{min} + Z_{max}) \\ Z_{max} - z & for\ z > \frac{1}{2}(Z_{min} + Z_{max}) \end{cases} \quad (7)$$

In order to recover high dynamic range radiance values, Equation 7 has been applied to obtain an optimal available exposures for a particular pixel. The function of recovering high dynamic range radiance values can be expressed as Equation 8 [11].

$$\ln E_i = \frac{\sum_{j=1}^{P} w(z_{ij})(g(Z_{ij}) - \ln \Delta t_j)}{\sum_{j=1}^{P} w(Z_{ij})} \quad (8)$$

Since the acute leukemia slide images are captured in RGB color space, thus each channel of the RGB color space will be treated separately, yielding three independent response functions [11]. The algorithm chooses the scaling factor such that a pixel with value Z_{mid} will have unit exposure. Thus, any pixel with the RGB value (Z_{mid} ; Z_{mid} ; Z_{mid}) will have equal radiance values for R, G, and B color space respectively, meaning that the pixel is achromatic, where Z_{mid} is obtained by Equation 9 [11] .

$$Z_{mid} = \frac{1}{2}\left(Z_{min} + Z_{max}\right) \tag{9}$$

D. Tone Mapping

Tone mapping is a technique used in image processing to convert the HDR image to approximate the appearance of HDR image in a medium that has a more limited dynamic range. An HDR image cannot be displayed properly on standard displaying devices due to the current displaying devices have a limited dynamic range. A good tone mapping algorithm should be able to produce an image that approximates to the appearance of HDR images for displaying purpose by scaling each pixel of the HDR image to ensure the details in highlights and shadows show correctly on standard display devices.

One of the simple approach to implement tone mapping is linear scaling which scales the luminance range in HDR image in the range of display devices but this may cause the details of the image degrade significantly [4]. Logarithmic mapping is another approach of tone mapping which produce a more recognizable image due to human eye's response [12]. Thus, the proposed method applied Ward's tone mapping algorithm which is one of the popular algorithm that's based on logarithmic mapping. The algorithm applied histogram equalization to increase the contrast of the image to optimize the available dynamic range and restores the saturation and contrast lost caused by logarithmic mapping. The naive histogram equalization that used in Ward's algorithm can be expressed as Equation 10 [12].

$$\begin{aligned}\log\left(L_d(x,y)\right) &= \log\left(L_{d,\min}\right) \\ &+ \left[\left(\log\left(L_{d,\max}\right) - \log\left(L_{d,\min}\right)\right]\bullet P\left(\log L_w(x,y)\right)\end{aligned} \tag{10}$$

where L_d is display luminance, L_w is world luminance, $L_{d,\min}$ is the minimum display luminance (black level), $L_{d,\max}$ is the maximum display luminance (white level), and P is the cumulative distribution function of the histogram.

III. Result and Discussion

The proposed technique begins with the captured of several acute leukemia slide images under 40x magnification. In the experiment, three different images were selected for implementing the proposed technique which are underexposed, properly exposed and overexposed images. Figures 4(a), (b), and (c) show the AML images with intensity histogram which are underexposed, properly exposed and overexposed respectively. Whereas Figures 5(a), (b), and (c) show the ALL images with intensity histogram which are underexposed, properly exposed and overexposed respectively.

After acquiring the images, the proposed partial contrast technique with three different approaches were implemented on the images. Next is to implement HDR technique to combine all the resulting images obtained from partial contrast technique with three different approaches and reproduce the HDR image by using tone mapping technique. Figures 6(a), (b) and (c) shows the resulting HDR images with intensity histogram for Figures 4(a), (b) and (c) respectively, whereas Figures 7(a), (b) and (c) shows the resulting HDR images with intensity histogram for Figures 5(a), (b) and (c) respectively.

According to the results in Figure 6 and Figure 7, the details of white blood cells in AML and ALL have been improved significantly compared to the original images. Whereas, from the intensity histogram for Figure 6 and Figure 7, both images now have higher dynamic range and better contrast compare to the original images. Thus, the proposed technique is proven to be able to enhance the morphological features of acute leukemia slide images and improves the dynamic range of the images captured.

IV. Conclusions

This paper proposed HDR implementation on previously captured acute leukemia slide images by using contrast stretching technique to enhance the visibility of the morphological features of the existing images. The results presented showed that the morphological features of blast cells for underexposed, properly exposed, and overexposed images were enhanced and the dynamic range of the images were also improved. Thus, the proposed technique may benefits the further processes of acute leukemia diagnosis such as feature extraction and classification.

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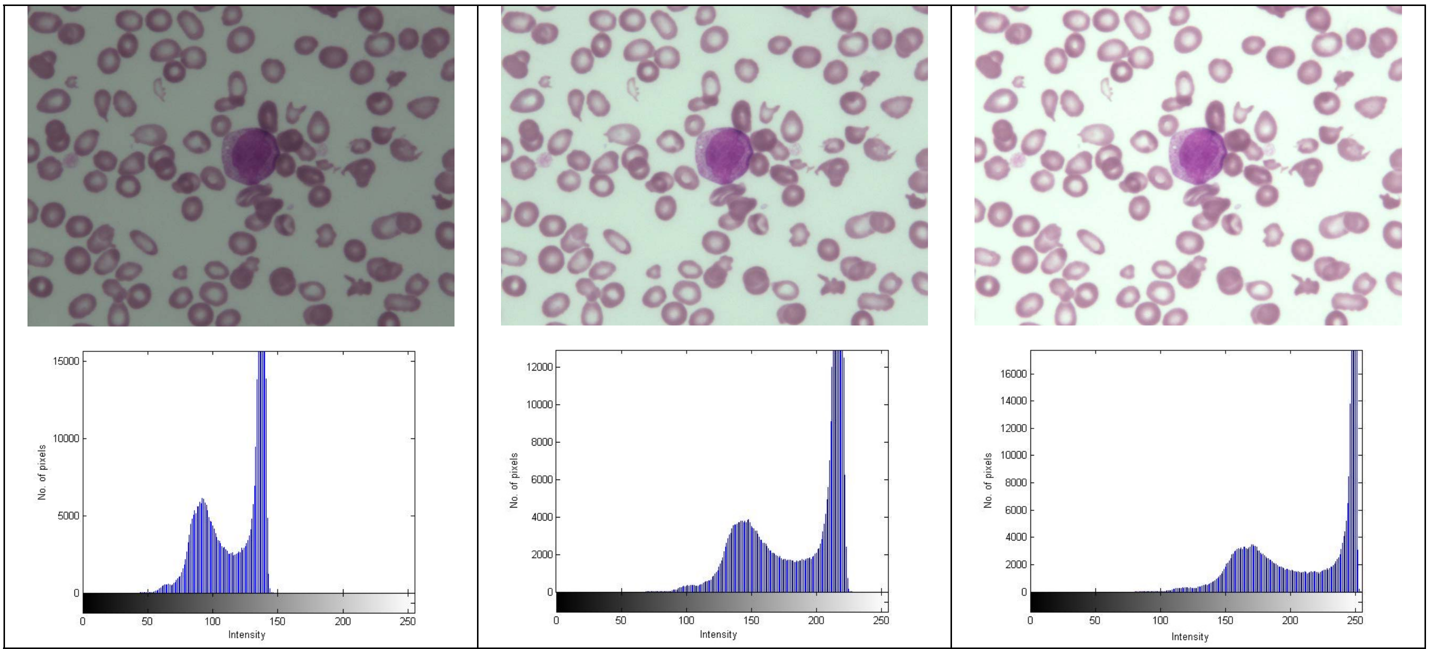
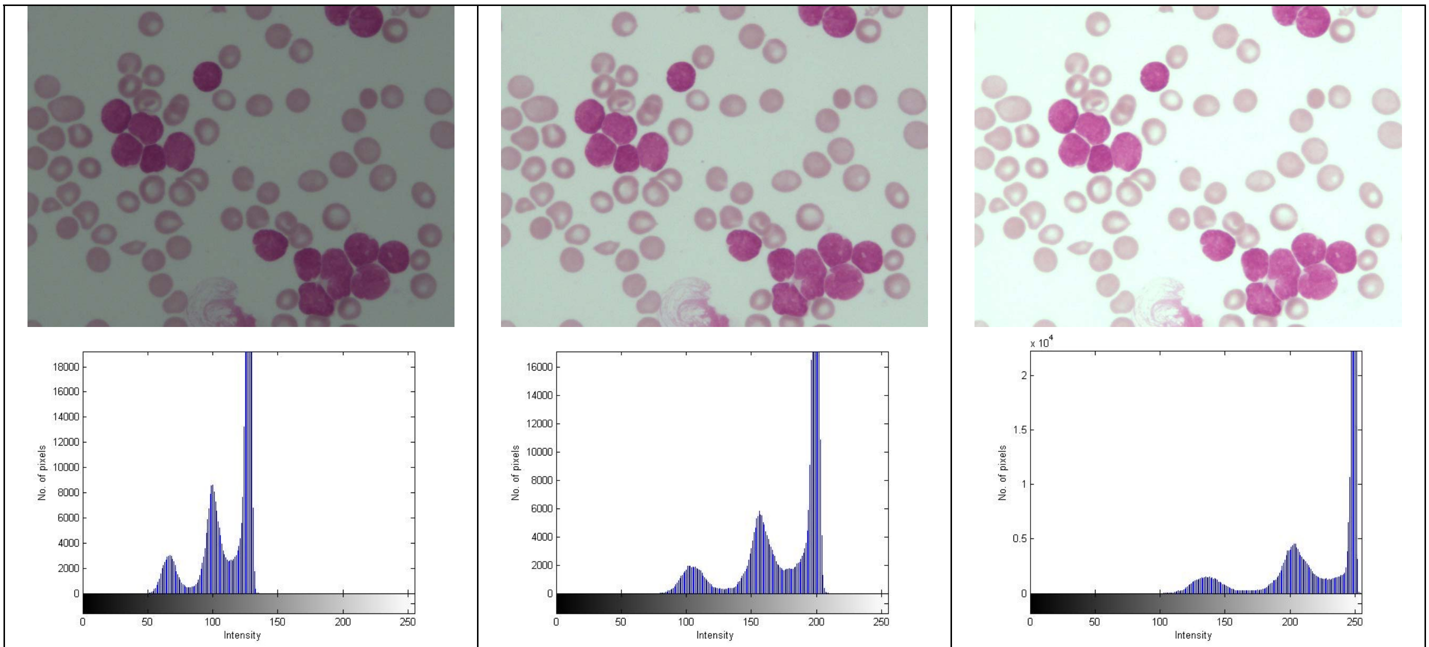


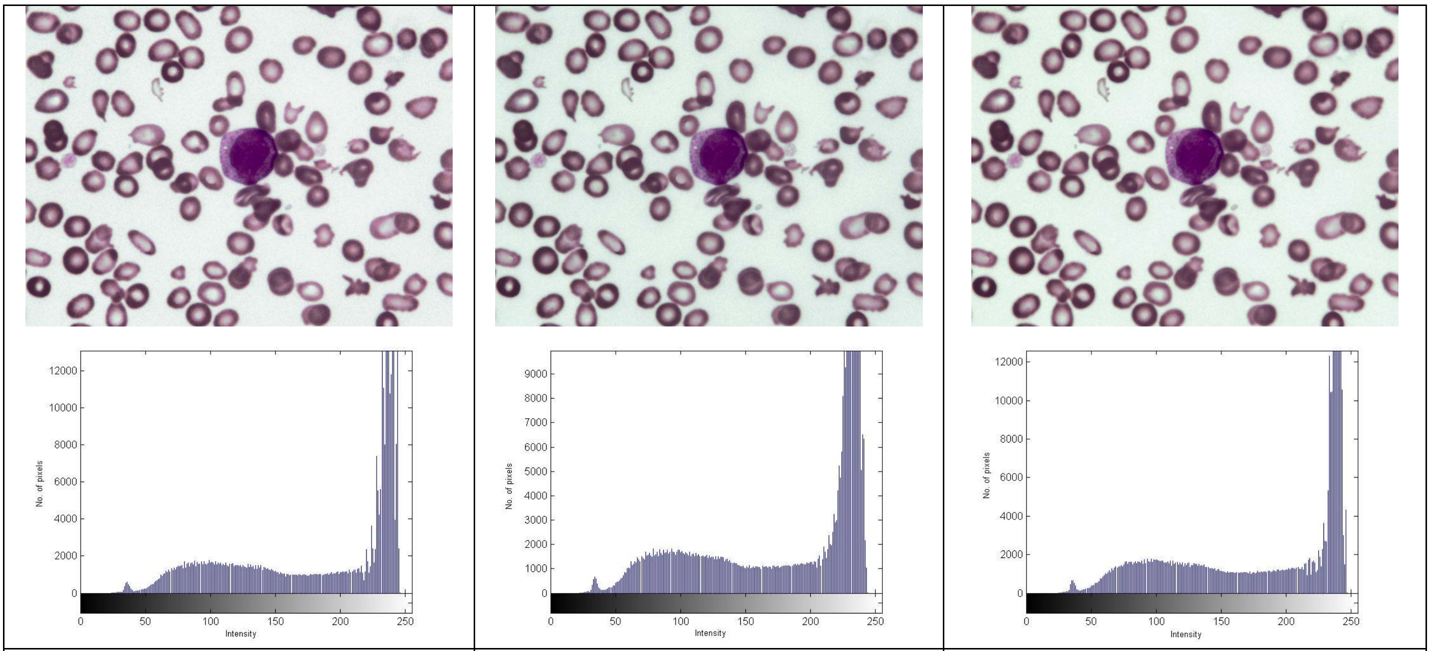
(a) Underexposed AML image	(b) Properly exposed AML image	(c) Overexposed AML image

Fig. 4. AML images with different exposure.



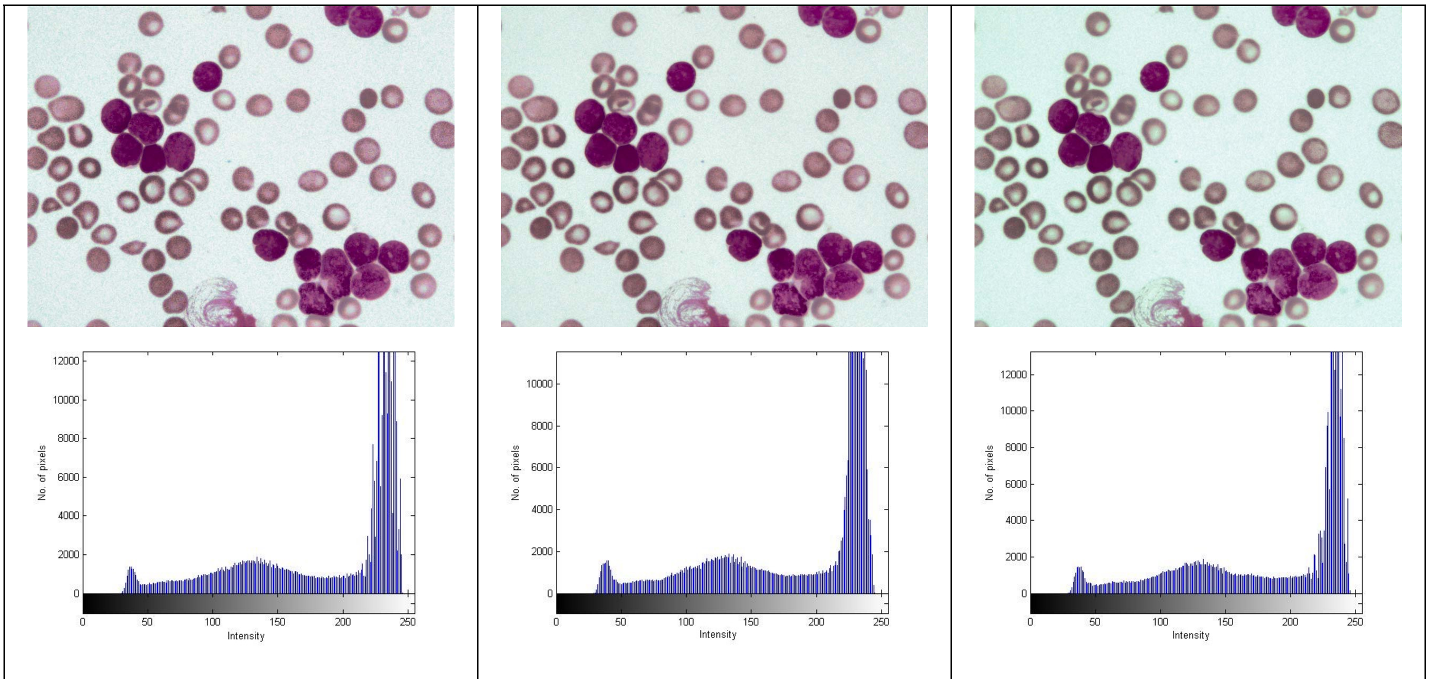
(a) Underexposed ALL image	(b) Properly exposed ALL image	(c) Overexposed ALL image

Fig. 5. ALL images with different exposure.



(a) HDR image for Figure 4(a)	(b) HDR image for Figure 4(b)	(c) HDR image for Figure 4(c)

Fig. 6 HDR images for AML.



(a) HDR image for Figure 5(a)	(b) HDR image for Figure 5(b)	(c) HDR image for Figure 5(c)

Fig. 7 HDR images for ALL.