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HIGH DYNAMIC RANGE IMPLEMENTATION ON ACUTE LEUKEMIA SLIDE IMAGES

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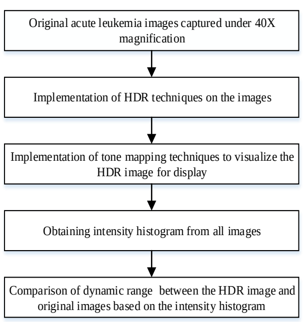
Graphical abstract



Abstract

Conventional diagnosis of acute leukemia is based on examining the morphology of the blood and bone marrow smear under the microscope and the process can be tedious, time intensive and highly skilled resources dependent. Over recent years, features fusion techniques base on statistical and morphological features had been explored in computer vision studies to enhance the capability of acute leukemia diagnosis task. However, microscopic image capture from the light microscope usually has poor quality due to the limited dynamic range of the camera. Thus, image regions with intensity levels outside the dynamic range captured by the camera sensor suffer from lack of details, appearing either underexposed or overexposed. This paper proposed a High Dynamic Range (HDR) imaging techniques to solve the problem of limited dynamic range and enhance the morphological features of blast cells. The proposed method consists of two main parts: implementing HDR techniques on acute leukemia slide images and comparing the dynamic range between HDR image and original images with different exposure time based on the intensity histograms obtained. The results presented showed that the HDR implementation has enhanced the morphological features of blast cells and increase the dynamic range, hence may benefit in the feature extraction and classification process of acute leukemia.

Keywords: Acute leukemia diagnosis, high dynamic range imaging.

Abstrak

Diagnosis konvensional leukemia akut adalah berdasarkan kepada pemeriksaan morfologi darah dan smear sum-sum tulang di bawah mikroskop dan proses ini amat menjemukan, mengambil masa yang lama dan bergantung kepada sumber manusia yang mahir. Kebelakangan ini, teknik penggabungan ciri-ciri statistik dan morfologi telah diterokai dalam kajian visi komputer untuk meningkatkan keupayaan tugas diagnosis leukemia akut. Namun, imej mikroskopik yang dirakam daripada mikroskop cahaya biasanya mempunyai kualiti yang rendah kerana julat dinamik kamera yang terhad. Oleh sebab itu, kawasan-kawasan imej dengan tahap intensitinya di luar julat dinamik yang dirakam oleh sensor kamera mengalami kekurangan perincian, kelihatan sama ada kurang dedahan atau lebih dedahan. Kertas kerja ini mencadangkan teknik pengimejan Julat Dinamik Tinggi (HDR) untuk menyelesaikan masalah julat dinamik terhad dan menambak baik ciri-ciri morfologi sel blas. Kaedah yang dicadangkan terdiri daripada dua bahagian utama: melaksanakan teknik HDR pada imej slaid leukemia akut dan membandingkan julat dinamik antara imej HDR dengan imej-imej asal yang berbeza masa pendedahan berdasarkan histogram intensiti yang diperolehi. Keputusan yang dibentangkan menunjukkan bahawa pelaksanaan HDR telah menambah baik ciri-ciri morfologi sel blas dan meningkatkan julat dinamik, dengan itu mungkin memberi manfaat kepada proses penyarian ciri dan klasifikasi leukemia akut.

Kata kunci: Diagnosis leukemia akut; pengimejan julat dinamik tinggi

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1.0 INTRODUCTION

Leukemia is a malignant disease or cancer of the bone marrow and blood characterized by an abnormal accumulation of blood cells, usually leukocytes (white blood cells). In other words, it begins in the bone marrow and then spreads to other organs according to the staging system. Leukemia is a general term used to describe four different types:

- Acute Myelogenous Leukemia (AML)
- Acute Lymphocytic Leukemia (ALL)
- Chronic Myelogenous Leukemia (CML)
- Chronic Lymphocytic Leukemia (CLL)

A diagnosis of leukemia is usually based on blood test and bone marrow examination following symptoms observed. Blood test consists of a complete blood count procedure to determine the number of red blood cells, white blood cells and platelets. The complete blood count (CBC) and peripheral blood film are the most commonly used blood tests by doctors by judging the morphological appearance of the leukemia cells for the purpose of diagnosis and classification. An abnormality of the white blood cell count and the presence of the leukemia cells (blast cells) may be suggestive of leukemia. The process can be tedious, time intensive and expensive, yet this classification is very important as it determines which treatment is given.

Recently, features fusion techniques have been explored by some researchers in computer vision studies. In the current study, some statistical and morphological features based on color, shaped, texture and so on will be extracted and fused to the morphological features to enhance the capability of the classification task. The color image processing approach will be used instead of the conventional gray level approach to enhance the features information. However, microscopic images captured from the light microscope usually have poor quality due to the capability of the camera. This is because a normal camera has limited dynamic range. Thus, image regions with intensity levels outside the range captured by the camera sensor suffer from lack of detail, appearing either underexposed or overexposed.

High dynamic range (HDR) imaging is a set of techniques which used to enhance the image quality by combining information from multiple images which have different exposure. With a wider range of exposure settings yields a higher potential dynamic range in the composite image and the image will look more naturally as seen directly from human eyes. In recent years,
HDR imaging has become increasingly popular, with rapid development of camera sensor and post-processing software.

The rapid development of HDR imaging techniques brings benefits to microscopy as well [1]. Microscopy image, usually has a wide range of optical densities, and consequently contain more intensity variation than can be captured with a single image by a digital camera. As computer based microscopy image analysis becomes popular, the need to acquire high quality digital images increases. Improper image exposure when operation a microscope may pose problems to many image processing techniques, and HDR imaging can eliminate this problem.

In this paper, the HDR rendering technique has been implemented on acute leukemia slide images that captured by a digital camera which has a limited intensity range. The HDR image is created from a series of three low dynamic range images that have different exposure times. Then, tone mapping technique is used to visualize the HDR image for display purpose. The performance of the HDR images is measured by comparing the dynamic range of HDR image with the original image based on the intensity histograms.

2.0 EXPERIMENTAL

2.1 Methodology

The specific morphological features of the abnormal white blood cell on the acute leukemia slide are important parameters for leukemia screening and diagnosis. These features including the size and shape of the white blood cells and the presence of Auer rode and multiple nucleoli in AML. Several image enhancement techniques have been applied to acute leukemia slide images such as contrast stretching [2-6] and histogram equalization. The goal of implementing HDR techniques on acute leukemia slide images is to enhance the visibility of the important features for the classification process. The proposed methods consist of few implementation steps:

a) Capturing the acute leukemia slide images under 40x magnification.
b) Implementing HDR technique on the original images to enhance the dynamic range and quality of the images.
c) Implementing tone mapping to visualize the HDR image on display which has limited dynamic range.
d) Obtaining intensity histogram from the original images and the HDR image.
e) Comparing the dynamic range between the HDR image and original images with different exposure time.

2.2 High Dynamic Range Imaging

Dynamic range is the ratio between the maximum and minimum value of intensity values present in a scene, camera and display. In real-world scenes, the dynamic range can be extremely wide. However, most of the cameras have only a limited dynamic range as compare with human eyes. Thus HDR techniques have been explored to increase the dynamic range of an image captured by merging multiple images with different exposure setting.

Debevec and Malik's algorithm [7] is one of the most popular HDR algorithm that is used in digital photography. This algorithm constructing high-dynamic range radiance maps by merging a series of photographs with different exposures. The radiance mapping can be expressed as Equation 1 [7].

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

where i is the spatial index over pixels, j is the indexes over exposure time Δt_j, N is the number of pixel location, P is the number of photographs, $g(Z_{ij})$ is the logarithmic response function, Z_{min} and Z_{max} are the pixel value boundaries, Z_{ij} is the pixel recorded at position i and exposure j, and $E_i$is the film irradiance value at image position i.

Whereas $g''(z)$ is the second derivative of g as expressed in Equation 2 [7] 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 3 [7].

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

$$w(z) = \begin{cases} z - Z_{min} & for\ z \le \frac{1}{2}(Z_{min} + Z_{max}) \\ Z_{max-}z & for\ z > \frac{1}{2}(Z_{min} + Z_{max}) \end{cases} \quad (3)$$

In order to recover high dynamic range radiance values, Equation 3 has been used to obtain an optimal available exposures for a particular pixel. The function of recovering high dynamic range radiance values can be expressed as Equation 4 [7].

$$\ln E_i = \frac{\sum_{j=1}^{P} w(z_{ij})(g(Z_{ij}) - \ln \Delta t_j)}{\sum_{j=1}^{P} w(Z_{ij})} \quad (4)$$

For the color image which consists of red, green and blue channels, each channel is treated separately, yielding three independent response functions [8]. Thus, any pixel with the RGB value will have equal radiance value for each channel and meaning that the pixel is achromatic [8].

2.3 Tone Mapping

Tone mapping is a technique used to convert the HDR image to a lower dynamic range image for display purposed. An HDR image cannot be displayed properly on standard display devices because of the current display devices have limited dynamic range. The goal of the tone mapping technique is to approximate the appearance of HDR images for display by scaling each pixel of the HDR image to ensure the details in highlights and shadows show correctly on standard display devices as well as suitable for printing.

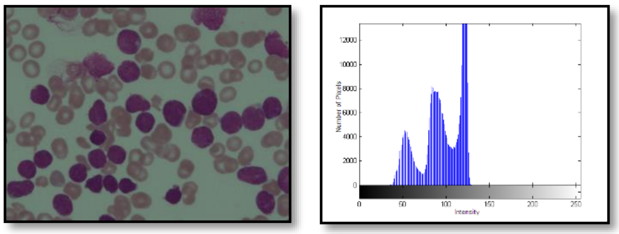
The simplest way of tone mapping is linear scaling which scales the luminance range in HDR image in the range of display devices but the details of the image may degrade significantly. Logarithmic mapping is another method of tone mapping which produce a more recognizable image. Ward's tone mapping algorithm [9] is one of the popular algorithm that's based on logarithmic mapping. The algorithm applies 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 naïve histogram equalization that used in Ward's algorithm can be expressed as Equation 5 [9].

$$\log(L_d(x,y)) = \log(L_{d,\min}) + [(\log(L_{d,\max}) - \log(L_{d,\min})] \bullet P(\log L_w(x,y)) \quad (5)$$

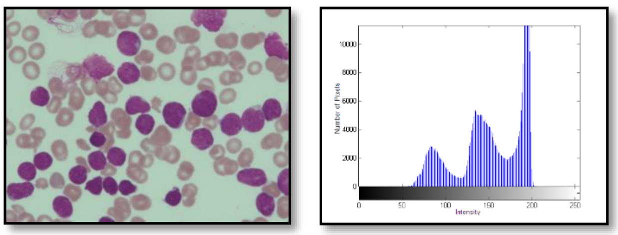
where L_d is display luminance, L_w is world luminance, $L_{d,min}$ is the minimum display luminance (black level), $L_{d,max}$ is the maximum display luminance (white level), and P is the cumulative distribution function of the histogram.

3.0 RESULTS AND DISCUSSION

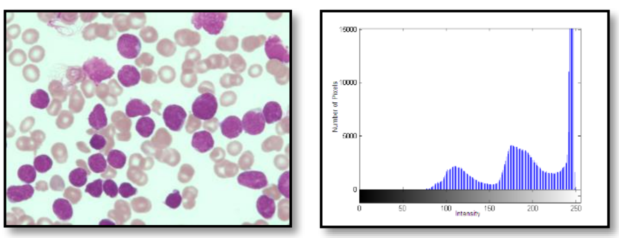
The proposed technique begins with acquired several images under different exposure time. Figure 1(a), (b), (c), (d), (e), (f), (g), (h), (i), (j), (k) and (l) show the ALL images and intensity histogram taken under exposure time of 10ms, 20ms, 30ms, 40ms, 50ms and 60ms respectively. Whereas Figure 2(a), (b), (c), (d), (e), (f), (g), (h), (i), (j), (k) and (l) show the AML images and intensity histogram taken under exposure time of 10ms, 20ms, 30ms, 40ms, 50ms and 60ms respectively.



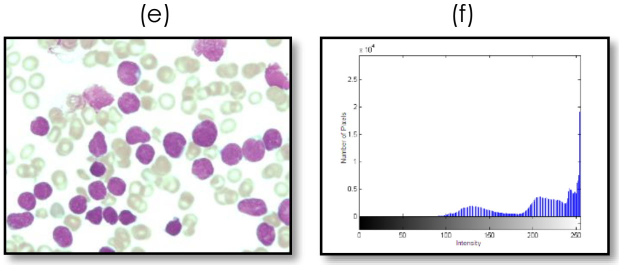
(a) (b)



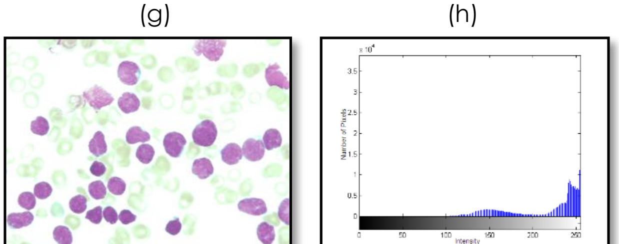
(c) (d)



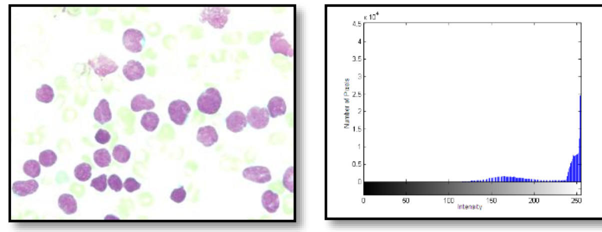
(e) (f)



(g) (h)

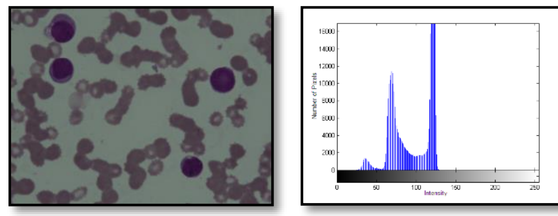


(i) (j)

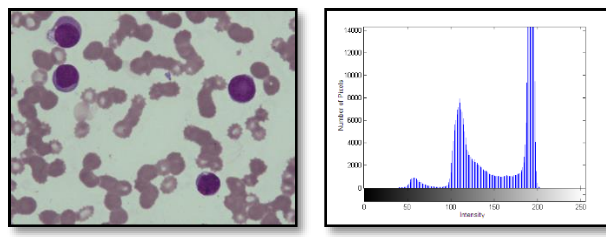


(k) (l)

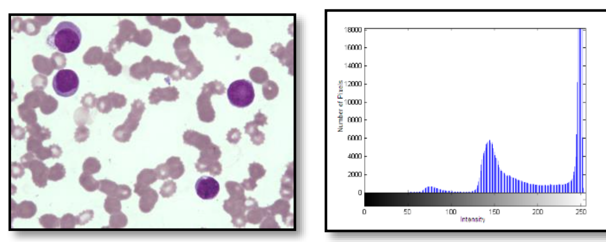
Figure 1 All images and intensity histogram taken under exposure time of (a)(b)10ms, (c)(d)20ms, (e)(f)30ms, (h)(g)40ms, (i)(j)50ms and (k)(l)60ms



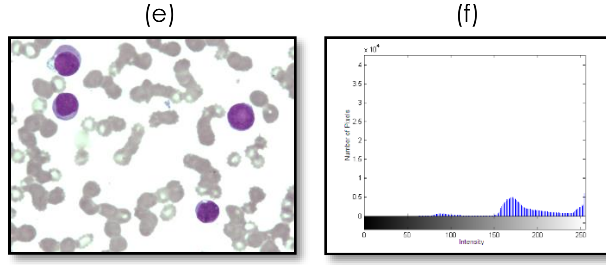
(a) (b)



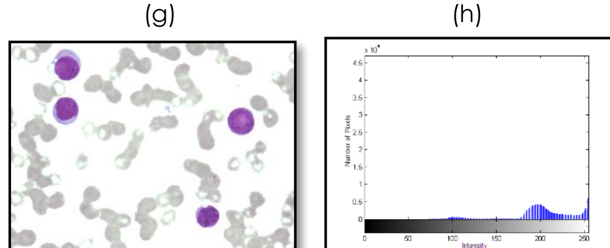
(c) (d)



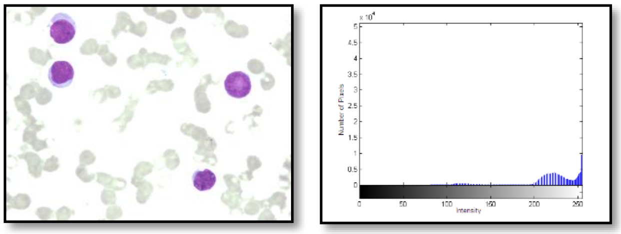
(e) (f)



(g) (h)



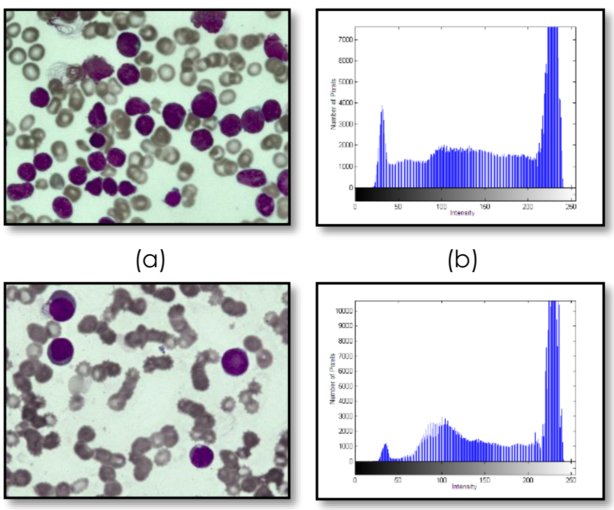
(i) (j)



(k) (l)

Figure 2 AML images and intensity histogram taken under exposure time of (a)(b)10ms, (c)(d)20ms, (e)(f)30ms, (h)(g)40ms, (i)(j)50ms and (k)(l)60ms

After acquiring the images under different exposure time, the next step is to implement the HDR algorithm to the images to create an HDR image and reproduce the HDR image by using tone mapping technique. The results of HDR image and intensity histogram for ALL and AML are shown in Figure 3(a), (b), (c) and (d) respectively.



(a) (b)

(c) (d)

Figure 3 HDR images for (a) ALL with (b) intensity histogram and (C) ALL with (d) intensity histogram

According to the result shown in Figure 3, the details of white blood cells in ALL and AML are improved significantly compared to the original images. Based on the resultant of intensity histogram in Figure 3, both of the pictures now have high dynamic range, which is fulfilled the range from 0 to 255. The overall dynamic range of the images has improved and the features in white blood cells are clearer in the HDR images.

Overall, HDR techniques has been proven that suitable be used for enhancing the morphological features of acute leukemia image and improved the dynamic range of the images captured.

4.0 CONCLUSION

This paper proposed HDR implementation on of acute leukemia slide images to enhance the visibility of the morphological features. The results presented showed that the morphological features of blast cells are enhanced and the dynamic range of the images are improved as well, hence may benefit in the feature extraction and classification process of acute leukemia.

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