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A novel enhancement technique for pathological microscopic image using neutrosophic similarity score scaling

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ABSTRACT

In 2011, Food and Drug Administration (FDA or USFDA) certified the automated cell morphology (ACM) systems for medical use in USA. The brightness, contrast and color appearance are all factors that play a major role in the diagnosis of many blood diseases. Accordingly, enhancement of pathological microscopic image (PMI) is a crucial step to increase the efficiency of computer assisted software. Some of the previous PMI enhancement methods neglected the illumination information and others used a reference image for template matching. These methods worked under strictly controlled conditions. In this paper, a robust technique is proposed for pathological images enhancement based on neutrosophic similarity score scaling. The color image is separated into three channels, and then each channel is represented in the neutrosophic domain into three subsets T, I and F. Neutrosophic similarity score (NSS) under multi-criteria are computed and used to scale the input image. The main contribution of this paper is that red, green and blue coefficients derived from the neutrosophic calculations lead directly to an adaptive pathology image enhancement and take into consideration many color image quality (IQ) parameters like illumination, contrast and color balance where it does not focus on a single IQ parameter like previous methods. In the experiments, several microscopic image quality measurements are utilized to evaluate the proposed method's performance versus the previous enhancement techniques. The experimental results demonstrate that our proposed system is promising with low complexity, adaptive with different resolution and lighting conditions. This provides the basis for automatic medical diagnosis and further processing of medical images.

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1. Introduction

Human visual analysis of microscopic blood samples plays an important role in the classification of many diseases. One of the PMIs is blood smear image which contain valued information about human health and disease. The cell's morphology structure is an essential feature to help the pathologist to decide the type of disease, and another one is the color appearance
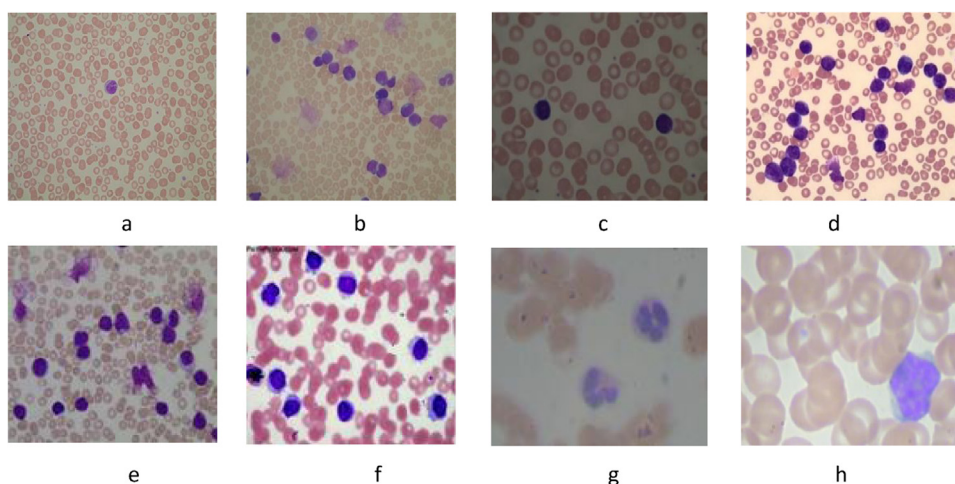
Fig. 1. Examples of degraded samples (a) low contrast image, (b) low contrast and low brightness image, (c) low brightness image, (d) good contrast good brightness, (e) good contrast low brightness, (f) good contrast good brightness, (g) low contrast and low brightness and (h) low contrast and low staining time.

of the each blood component, including red blood cells (RBCs), white blood cells (WBCs) and platelets [1]. The staining is a fundamental procedure which affects on the color appearance of each blood component [2]. After the staining procedure, the nuclei appear within cells blue and the cytoplasm appears with light blue, magenta or red according to the WBC type, which will constitutionally influence the diagnosis decision on various diseases [3]. The automated pathological imaging system (APIS) has been proved as an excellent tool in the pathological investigation and analysis. It is composed of a microscope, a charge coupled device (CCD) camera, a computer providing many operations such as digitization, storage, retrieval or viewing it on the monitor. Microscopic images are used for counting cells, analyzing shape and structure of cells and cell distribution [4].

Usually, pathological images do not have the same image quality parameters like color appearance, contrast, brightness, and resolution. This difference may be present in any procedure of APIS starting from staining and ending with imaging restoration. The difference of imaging acquisition system according to the variety of APIS in the industry will affect directly the image resolution and its quality parameters, leading to vague brightness, and low contrast, and low signal to noise ratio. Staining time also plays an important role in the contrast of the pathological image and each object intensity, as low staining time gives low sample intensity [5].

The challenge to be solved in many microscopic images is to find an adaptive preprocessing technique for each image under different conditions. In Fig. 1, different samples are collected from different datasets with different imaging conditions like resolution, contrast, brightness and background color. Fig. 1a and b have low contrast. Fig. 1c has low brightness. Fig. 1d–f are ideal images where each blood component appears at good contrast and brightness with a clear background. Fig. 1g and h have low contrast and weak cytoplasm appearance, mostly due to short staining time. There also variations between these images. In Fig. 1a, d, f and g, there are different background colors. Staining artifacts in the background are found in Fig. 1b and g. In Fig. 1c and e, different brightness in the same sample, different color contrast values. In Fig. 1h, the weak appearance of the cytoplasm is noticed compared to the cytoplasm color appearance in Fig. 1f.

Most of the published methods only worked on images under strictly controlled conditions. By contrast, in practical applications, the blood smear images to be analyzed do not always have good color consistency. Therefore, color adjustment for blood smear images is necessary [6]. Accordingly, there is a genuine need to adaptively restore degraded images from different APIS platforms.

In the pre-processing procedure of microscopic images, numerous approaches were proposed specifically for contrast enhancement. These methods include contrast adjustment by a combination of shifting of color values and linear transformation [7], nonlinear fixed transformation of the gray levels [8], and histogram stretching [9]. Moreover, histogram equalization (HE) [9], contrast limited adaptive histogram equalization (CLAHE) [10] and its modifications [11]. These techniques were popularly employed for their simplicity and good performance over a variety of images. However, they also established major changes in the pixels values and produce some distortion [12].

Other approaches were employed specifically for PMI enhancement like ̈rg chroma ̈[13] which was not correlated with brightness changes and neglect the illumination values. In [14], a general technique for color correction was proposed. The technique depended on CIE-Lab color space modification to correct the brightness and contrast of the image. However, this method was not robust as it needed a standard high-quality pathology image as a reference to correct the degraded one [6].

Neutrosophic set (NS) is a new general formal framework to study the neutralities, origin, nature, and scope. Any indeterminant information can be handled with its inherent ability. The neutrosophic transform (NT) has been used in many applications in image processing such as image enhancement [15], image thresholding [16], edge detection [17] and so on.