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Retinex based Color Constancy Algorithm for Cancerous Cell Detection under various Illuminations

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Abstract : Histopathological analysis of biopsy specimens is essential for diagnosing and characterizing cancer. Computer-aided cancer diagnostic tools aid pathologists in making objective and timely decisions. Feature extraction and data mining are the key components of diagnostic systems. For a system with a single data source, we can expect sample images to have the same spatial resolution, magnification and stain colors. However, if the images are acquired from separate set-ups, images suffer from both color and scale variations. Histopathology diagnosis is based on visual examination of the morphology of histological sections under a microscope. With the increasing popularity of digital slide scanners, decision support systems based on the analysis of digital pathology images are in high demand. However, computerized decision support systems are fraught with problems that stem from color variations in tissue appearance due to variation in tissue preparation, variation in stain reactivity from different manufacturers/batches, user or protocol variation, and the use of scanners from different manufacturers**.** Likewise, images of a panorama captured with several cameras will have different color values because of variations in color reproduction across devices. Human beings tend to disregard the illumination when judging object appearance. The objective of color normalization algorithms is to carry out a comprehensive modification of the color intensities in an image so that the reproduced image captures the true color features of the object. This paper presents a comparative study of color normalization algorithms such as Retinex, Grey Edge and Histogram equalization.

Keywords: Retinex algorithm, Grey edge, Histogram equalization, MATLAB, Color normalization

1. INTRODUCTION

Image enhancement plays a fundamental role in image processing where human experts obtain an important decision based on the imaging information. The goal of an image enhancement algorithm is to reconstruct the recorded image similar to that of the true picture. Medical image enhancement [1] is one of the key research fields for the researchers due to widespread use of medical images in the diagnosis of various lesions. Histopathology is an integral part of the detection, monitoring and research of cancer.Color variations affect color based image features and color-based segmentation, hence affecting the diagnostic performance of the model. In order to examine tissue sections (which are virtually transparent), tissue sections are prepared using colored histochemical stains that bind selectively to cellular components. Color variation is a problem in histopathology based on light microscopy due to a range of factors such as the use of different scanners, variable chemical coloring/reactivity from different manufacturers/batches of stains, coloring being dependent on staining procedure (timing, concentrations, etc.), and light transmission being a function of section thickness. With the advent of digital imaging and automatic image analysis, color variation in histopathology has become more of an issue. For example, many commercial image analysis algorithms require parameters defining the expected color of anatomy of interest and fail if these parameters are incorrect. Although methods have been proposed for improving color constancy in images formed via Lambertion model [2] of image formation, these methods are not applicable to color images formed via light transmission through a tissue specimen, and thus are inappropriate for histopathology image analysis. Consequently, a large number of methods presented in the area of automatic image analysis of color histopathology images bypass the problem of color constancy by transforming the images to grayscale. The term "stain or color normalization" is used to refer to the process of adjusting the color values of an image on a pixel-by-pixel basis so as to match the color distribution of the source image to that of a target image. Automated processing of digital histopathology slides has the potential to streamline patient care and provide new tools for cancer classification and grading. Before automatic analysis is possible, quality control procedures are applied to ensure that each image can be read consistently. One important quality control step is color normalization of the slide image, which adjusts for color variances caused by differences in stain preparation and image acquisition equipment. Color batch-effects affect color-based features and reduce the performance of supervised color segmentation algorithms on images acquired separately. Three color normalization algorithms are compared in this paper using cancer image which is taken under different lighting conditions.

Histogram specification [3] is a method closely related to histogram equalization that was previously used for color normalization in oral histopathology images. A major drawback of histogram-based approaches is that they introduce considerable visual artifacts in images. This is due to the implicit assumption that the proportion of pixels of each stain type is same in the target and source images. Kothari et al. [4] proposed a variation on histogram normalization, where the presence of a color, rather than frequency is used for color normalization. Reinhard et al. [5] proposed a method of color normalization where the mean and standard deviation of each channel of the image are matched to that of the target by means of a set of linear transforms in Lab colorspace. However, the assumption of unmoral distribution of pixels in each channel of Lab colorspace does not hold if multiple colored stains are used. As a result, this can result in background areas being mapped as colored regions, and foreground being incorrectly mapped.

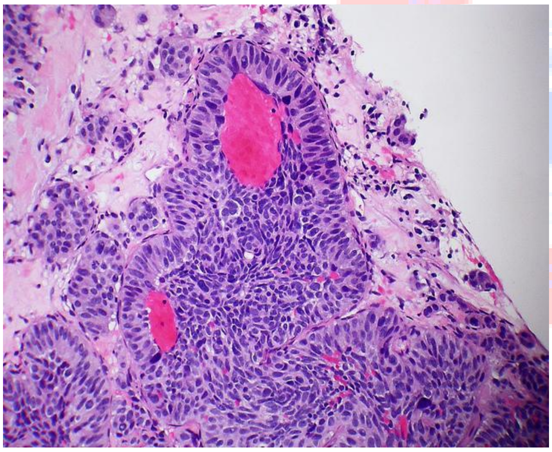
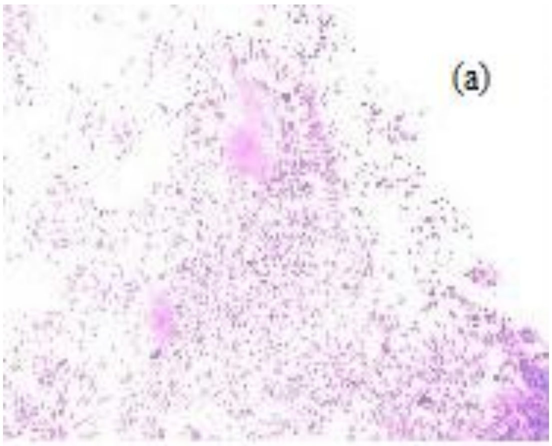


Figure 1: Source image of cancerous cell



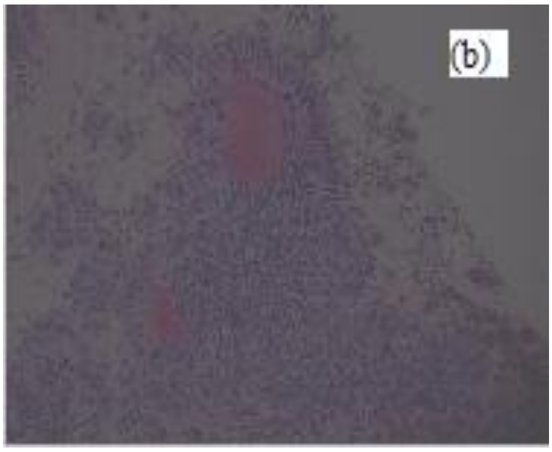


Figure 2: Image under different illuminations like (a) bright light (b) dark illumination and (c) low contrast

2. COLOR CONSTANCY ALGORITHMS OVERVIEW

A vast number of algorithms present for achieving color normalization and a limited number of algorithms have been presented in this paper. It is important to note that performance of an algorithm is dependent on the task. The algorithm which performs better in one task may perform worse in another task. The choice of the algorithm depends on the preferences of the user for the final result, which is more natural looking image.

2.1 Histogram equalization

Histogram processing is the act of altering an image by modifying its histogram. Common uses of histogram processing include normalization by which one makes the histogram of an image as flat as possible. Histograms are simple to calculate in software and also lend themselves to economic hardware implementations, thus making them a popular tool for real-time image processing. It is extensively used for medical image processing and as a pre-processing step in speech recognition, texture synthesis and many other image/video processing applications. Histogram equalization allows for areas of lower local contrast [6] to gain a higher contrast and automatically determines a transformation function seeking to produce an output image with a uniform histogram. The sum of all components of a normalized histogram is equal to 1. The histogram of digital image with the intensity levels in the range [X_0, X_{L-1}] is a discrete function. Histogram equalization is a scheme that maps the input image into the entire dynamic range [X_0, X_{L-1}] by using the cumulative distribution function as a transform function. This method is useful for the images which are bright or dark.

2.2 White patch retinex

The Retinex algorithm relies on having a bright intensity area somewhere in the image. The idea is that if there is a white area in the scene, then it reflects the greatest light possible for each band. If one assumes a linear relationship between the response of the sensor and pixel colors, then the light illuminating the scene simply scales the product of the Geometry term (G) and the Reflectance (R_i) of the object [7]. Rescales all the color bands where a bright patch is located.

Step 1: Input an RGB image

Step 2: For each of the color channels find intensity I_i

where i = {1, 2,3} for R, G and B.

Step 3: For the Retinex, the centre is defined as each pixel value and the surround is a Gaussian function. The mathematical form of Retinex is given by,

$$R(x,y) = \log[I(x,y)] - \log[I(x,y)*F(x,y)] \quad \ldots..1$$

where, I is the input image.

R is the Retinex output image and F is the Gaussian filter (surround or kernel) defined by,

$$F(x,y) = K*\exp[-(x^2+y^2)/\sigma^2] \quad \ldots2$$

where, σ is the standard deviation of the filter and controls the amount of spatial detail that is retained, and K is a normalization factor that keeps the area under the Gaussian curve.

Step 4: Return the resultant image output.

2.3 Grey-edge (L*a*b) color space

L*a*b color space is a color space with dimension L* for lightness and a* and b for the color magnitude. The Grey edge algorithm is based on estimation of color of multiple sources of light. Most of the methods developed in past research were based on single uniform source of light [8]. Image enhancement is a very simple yet useful concept that allows us to change the brightness and contrast of a gray level display. The principal objective of enhancement is to process an image so that the result is more suitable than the original image. The overall goal of this algorithm is to propose a 2nd order grey edge based color constancy algorithm. The histogram stretching is also used to improve the results.

The majority of color constancy algorithms are based on one light source, i.e. they are based on the assumption of spectrally uniform lighting. However in real world, an image may be affected by multiple sources of light. The Grey edge algorithm is based on estimation of color of multiple sources of light. This algorithm is designed to create the edge based color constancy since most of the details are presented by the edges of an image. The grey world algorithm is based on the assumption that the average reflectance of surfaces in the world is achromatic.

Grey Edge using 1st order derivative does not prove to be efficient because each pixel considers its 4 neighbouring pixels. So, in this method not all information is available for color correction [9]. In computer vision, the Grey edge algorithm is essential for many applications such as image retrieval, colour reproduction and object recognition. The algorithm is given below.

Step 1: Input an RGB color image and find the size of an image.

Step 2: Convert the RGB image to L*a*b color space

Step 3: Remove the saturation color points which are heavily affected by light source.

Step 4: Find the luminance component of an image.

Step 5: After measuring the light source, color normalization will be done to each of the color channels to balance the effect of the poor light.

Step 6: Histogram stretching and adaptive Histogram equalization will be applied to get the color corrected image.

3. RESULTS

Input test images under various illuminations such as bright light, dark illumination and low contrast illumination are as shown in Figure 3.

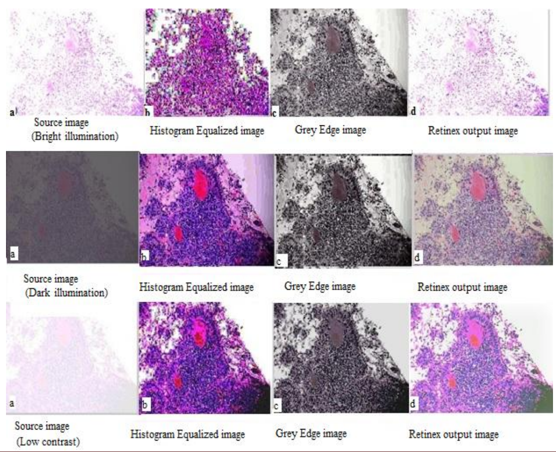


Figure 3: Resultant output images after the application of algorithms

4. ANALYSIS OF VARIOUS QUALITY METRICES

Comparative analysis of various quality metrics is done on medical images taken under three different kinds of lighting conditions such as bright, dark and low contrast illuminations. Output results are analyzed for comparison of various quality metrics such as Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE), Normalized Absolute Error (NAE) and Normalized Cross Correlation (NCC) as shown from Table 1 to Table 3. These are appealing because they are simple to calculate, have clear physical meanings, and are mathematically convenient in the context of optimization.

$$MSE = (1/MN)\ \Sigma\Sigma[X(i,j) - Y(i,j)]^2 \qquad ..3$$

$$PSNR = 10\log_{10}(2^n-1)^2/\mathrm{sqrt}(MSE) \qquad ..4$$

$$NAE = 1/MN\Sigma\Sigma\left|X(i,j) - Y(i,j)\right| \qquad ..5$$

$$NCC=\Sigma\Sigma[X(i,j)*Y(i,j)]/[X(i,j)]^2 \qquad ..6$$

where M, N = size of an image; i =1,2……..M; j =1,2……..N; X being the original image and Y being the enhanced image.

Table 1. Source image taken under bright illumination

Errors / Algorithm	PSNR	MSE	NAE	NCC
Histogram	29.012	81.62	245.8	0.0027
Grey Edge	29.014	81.59	244.5	0.0024
Retinex	33.256	30.717	92.18	0.0057

Table 2. Source image taken under dark illumination

Errors / Algorithm	PSNR	MSE	NAE	NCC
Histogram	46.29	1.52	0.018	0.983
Grey Edge	32.14	39.69	74.27	0.52
Retinex	99	24.74	0.80	1.82

Table 3. Source image taken under low contrast

Errors / Algorithm	PSNR	MSE	NAE	NCC
Histogram	31.59	45.08	84.20	0.459
Grey Edge	35.70	18.32	57.72	0.782
Retinex	99	10.58	0.225	1.392

5. CONCLUSIONS

Comparative evaluation of various quality metrics has been done in MATLAB with three different kinds of illumination conditions for an image with cancerous cells, which commonly finds its application in the area of medical image processing. From the results, it is clear that PSNR is maximum, MSE and NAE is minimum and NCC is nearly equal to unity in case of Retinex algorithm. Thus it can be concluded that Retinex algorithm suits better for medical imaging applications. Further, it can be used for object as well as face recognition.

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