On Correcting Luminosity and Contrast of Retinal Images with Reflectance

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Abstract

In this paper, we perform an automatic correction of luminosity and contrast of retina images. One hundred retina images with varying level of reflectance taken from custom and online databases are used to test the effectiveness of the proposed method. The approach is implemented in 4 stages namely pre-processing, lowpass filtering, luminosity equalization, and contrast stretching. In the pre-processing stage, the three components of a color retina image are separated and only the green channel is processed further as it contains the most information. Then the region of interest (which is the eye region) and its border are marked. After that, the eye region (ROI) of the green channel is subjected to lowpass filtering, row by row to create a smooth background luminosity surface without the foreground objects like the optic disc, exudates, blood vessels and blood spots. Three different types of lowpass filters are used and their performances are compared. The resulting background luminosity surface allows the estimation of the background illumination. Then, based on the background surface, the luminosity of the ROI is equalized so that every pixel experiences the same brightness. Finally, the contrast of the ROI is improved by histogram stretching so that the foreground objects appear more clearly. The proposed method was implemented using MATLAB R2021b running on AMD 5900HS processor and the average execution time was less than 1 second. The execution time can be further reduced if the codes are optimized and GPU is used. Overall, the proposed method improves the luminosity and contrast of the images greatly. This technique can be a useful tool to ophthalmologists who perform visual inspection of microaneurysm, exudates and other lesions.

Keywords: Retina Images, Luminosity, Contrast, Reflectance, Lowpass Filters.

1. Introduction

Ophthalmologists examine the foreground and background of retina images to assess the eye condition of a patient. As the process is time-consuming, it becomes daunting when there are many patients to diagnose. Therefore, computer assisted diagnosis is an invaluable tool that expedites the process and increases its effectiveness. The quality of retina images plays an important role in ensuring the accuracy of diagnosis. Retina images may suffer from uneven illumination, blurring, and low contrast. Image enhancement can improve the quality of an image for a better visual perception. For retina images suffering from luminosity and contrast variation, many image enhancement methods have been proposed to overcome these issues [1][2][3][4]. The methods are categorized into two main groups namely spatial and frequency domain approaches. Spatial domain approaches work directly with the pixels of an image where the pixel values are transformed or altered [5][6]. Techniques that manipulate pixels directly include logarithmic transforms, power law transforms, and histogram equalisation. Meanwhile frequency domain uses Fourier transform (FT), discrete cosine transform (DCT), and discrete wavelet transform (DWT) to convert an image to another domain, then manipulate it and then inverse transform the outcome to its original image space [7][8].

Most color retina image enhancement methods work in HSV or LAB color space to improve the luminosity of the images. Then contrast is improved using histogram equalization and other techniques [7][8][9][10]. There are also a few methods that work in RGB space but it is more difficult to improve color images in RGB space since the color tone can change if the color components are not adjusted carefully. The majority of the works are done in greyscale and so does our method.

The work presented here is a spatial domain approach. The method utilizes spatial filtering to improve and enhance the luminosity and contrast of images respectively. The rest of this paper is organized as follows. Section 2 describes the methodology of the proposed method. Section 3 presents the initial experimental results, and Section 4 provides the conclusion.

2. Methodology

Periodic evaluation of retinal images is important to patients suffering from retinopathy. Here, we propose a new method to correct both luminosity and contrast of retina images that are affected by strong reflectance. The process is executed in four stages which are pre-processing, filtering, luminosity adjustment, and contrast stretching. Fig. 1 shows the flow of the process.

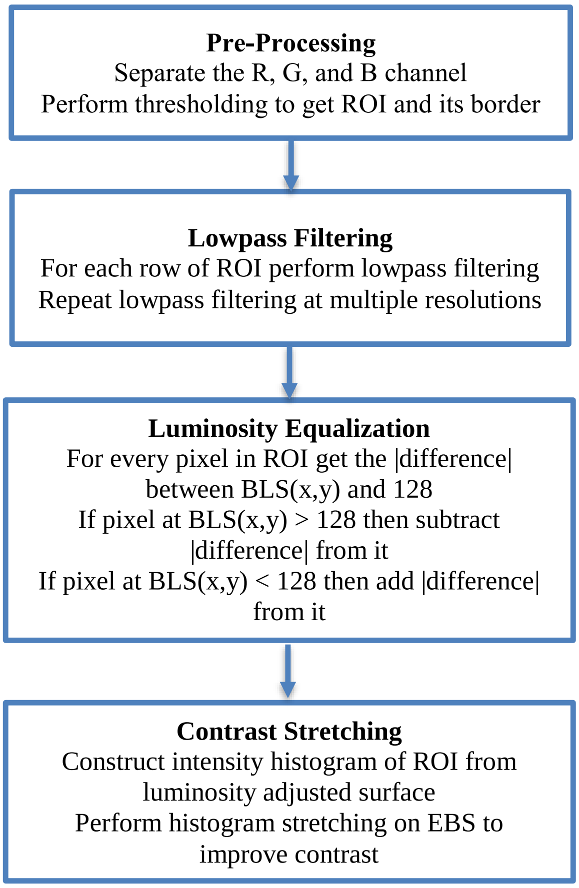

Fig. 1 Flow of stages in the process

In the pre-processing stage, the red, green and blue (RGB) channels of the retina image are separated. At this juncture, the red and blue channels can be dropped. However, they can also be processed if deemed necessary. The green channel G(x,y) is further processed as it is deemed to contain the most information. First, the area of the eye and its border are identified by thresholding. We realize that in the ROI of an image that suffers from reflectance, the centers of reflectance are located in the vicinity of its border. After locating the reflectance centers, measures can be taken to reduce the effects of reflectance before lowpass filtering.

Next, in lowpass filtering stage, each row of the ROI is processed one by one. First, the intensities of all pixels in a row are stored in an array. Then the array is subjected to lowpass filtering at three resolutions to smoothen its values. For this purpose, we perform downsampling to lower the resolution of the image. Then upsampling is performed to increase the size of the images back to its original scale. Three different filters are tested, and they are the median filter, Gaussian and moving average filters. The length of the filter is 11, 13 and 15 for the three resolutions. The image can be further smoothened column by column using the same filters. Once the lowpass filtering step is completed, the result is a smooth estimate of the background surface for the image called the background luminosity surface (BLS). The BLS represents the background luminosity of every pixel in the image without foreground objects. As the ROI is small, it is logical to assume that the background luminosity of every pixel should be equal. Hence, the luminosity of each pixel should be corrected and made the same. In our experiment, our target is to level the average intensity of all pixel in an image to 128. This value is chosen since it is the middle intensity value for normal images represented by eight bit unsigned integer. The intensity of each pixel G(x,y) in the input image can be higher or lower than its background luminosity in the BLS(x,y). So, at every location (x,y) in the ROI, the difference between the input G(x,y) and its background BLS(x,y) is calculated and recorded. This difference shall be maintained even after the background BLS(x,y) is adjusted to 128 to equalize the background brightness for each pixel in the ROI. The result of equalizing the background of the input image G(x,y) is an image with evenly spread luminosity called equalized brightness image (EBI). Keep in mind that the difference between G(x,y) and BLS(x,y) is always added to 128 at every location (x,y).

The next step is to perform histogram stretching on the ROI of EBI(x,y) to improve its contrast. First the histogram of intensity frequency of the image is constructed. Then the histogram spread is calculated. It is the difference between the highest and lowest intensities in the image. Then the histogram is stretched so that its spread occupies the whole range of 0 until 255. Of course, this method only works if the histogram spread is less than 255 to start with. Otherwise, histogram equalization or CLAHE can be used instead of histogram stretching to improve the image contrast.

It is not necessary for the red and blue channels to be processed along with the green channel. However, they can be subjected to the same treatment if required. Details from the red and blue channels can be incorporated into the green channel to enhance its appearance and contrast. Fig. 2 shows the green channel of an input image G(x,y) and its BLS, EBI and contrast stretched EBI (CEBI). As seen, there is little difference between EBI and CEBI of the image. This is because histogram stretching does little on an image which already has a good contrast. It is also possible to combine both histogram stretching and equalization to improve an image. However, the effect is almost similar to histogram stretching or equalization alone. It is also noted that the effect of boundary reflectance at the top border of the image is completely gone in CEBI. It seems that the method is just as effective for images that require luminosity and contrast adjustments without suffering from strong boundary reflectance.

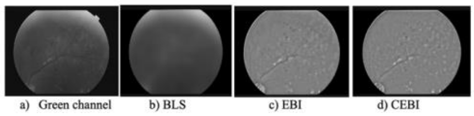

Fig. 2 The green channel of an image and its BLS, EBI and CEBI

3. Results and Discussion

In this work, 100 retina images taken from custom and online databases were utilized to test the performance of the proposed method. It turned out that the results produced by the Gaussian and moving average filters were almost identical. The results of median filter were not as good as those of the other two filters because some important details of the foreground objects were eliminated by the filter. Perhaps this is because median filter is a nonlinear lowpass filter. However, the execution times of all three filters were less than 1 second. If the codes are optimized and the GPU unit is used, they can be made lower. The best performance belongs to the moving average filter since it records the fastest time in implementation and generates the best result. On average, the proposed method manages to reduce 30% luminosity variation and increase the contrast of the greyscale images by more than 100%. Luminosity variation is implied from the standard deviation of the pixel intensities in the images and contrast is calculated using the metric proposed by Matkovic et. al [12]. It is similar to the sum of absolute difference calculated at three different resolutions. The approach was implemented on a laptop powered by an Intel i7 processor using MATLAB R2021b. This technique can be a useful tool to ophthalmologists who perform visual diagnosis of microaneurysm, fundus and other lesions. Fig. 3 shows five samples of retina images whose luminosity and contrast have been corrected using the proposed method. As seen, all of the boundary reflectance effects are removed from the images.

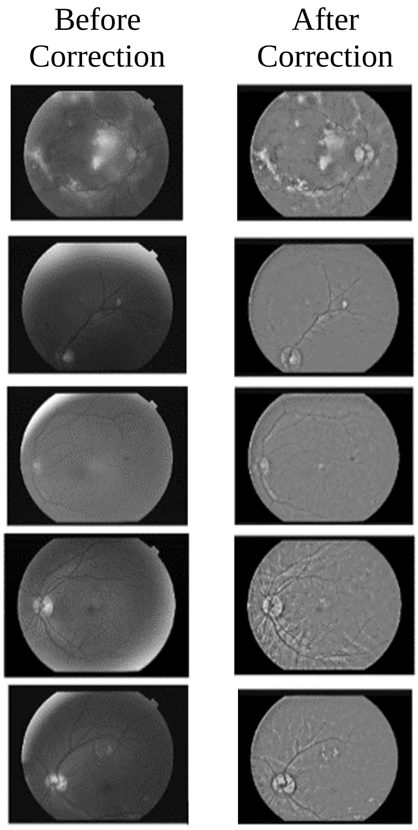

Fig. 3 Five samples of retina images before and after correction.

4. Conclusion

In this work, a new method to rectify luminosity and contrast variation in retina images is introduced. The method successfully removes luminosity variation and improves the contrast of the images even when they suffer intense reflectance. If a post filtering stage is introduced, details of the adjusted green channel can be further enhanced using information from the red and blue channels. The performance of the approach is tested on 100 test images and improvement is noticeable visually and quantitatively for both luminosity and contrast. On average, this method manages to reduce 30% luminosity variation and increase the contrast of the retina images significantly.

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