AN AUTOMATED APPROACH FOR PREPROCESSING RETINOGRAPHIES

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Abstract: A retinography is a retinal photography useful for the precise tracking of any retinal pathology, especially the glaucoma. Although there are sophisticated procedures for studying the evolution of the optic nerve, sometimes it is not feasible the development of a rigorous tracking due to the high number of patients, the high cost of the procedure and the need of high qualified staff. The design of an automated method for detecting this pathology in its first stages through the automated analysis of retinographies could reduce the cost of the process and the number of required specialists. Inspired by this objective, an automated preprocessing method for retinographies is presented in this paper. The proposed methodology combines information of different color spaces for achieving illumination and contrast enhancement.

1 INTRODUCTION

A retinography is a retinal photography useful for the precise tracking of any retinal pathology, especially the glaucoma. Glaucoma refers to a group of diseases that affect the optic nerve and involves a loss of retinal ganglion cells in a characteristic pattern. Glaucoma without treatment leads to an irreversible damaged of the optic nerve and to a loss of the visual field that could originate partial or total blindness. Therefore, one of the regions of interest in the study of retinographies is the optic nerve head (ONH).

Glaucoma is the most frequent cause of blindness in the industrialized countries. The best prevention method to delay its evolution and avoid the vision loss is the regular tracking of the medical treatment. The design of an automated method for detecting this pathology in its first stages through the automated analysis of retinographies could reduce the cost of the process and the number of required specialists.

The application of image processing techniques on the retinography analysis is an increasing research field. These techniques are not automated and they normally require the user intervention. The computer techniques for processing eye fundus images usually involve the manual or semiautomatic draw of the papilla contour and other structures of the ONH. However, the objective of minimizing the human intervention in these systems is appearing in related research works (Cox et al., 1991), (Iqbal et al., 2006), (Teng et al., 2002).

The work presented in this paper is part of a research project developed in collaboration with the Hospital Universitario de Canarias. The main objective of the project is the design of an automated software system for the delimitation of the ONH and for the differentiation of superimposed structures (arteries, vessels). Due to the irregularities presented in the analyzed images it is essential to carry out a preprocessing stage, in order to improve the image before developing segmentation of the different regions of interest. This enhancement process is the core of this paper.

The problem of preprocessing retinographies has been tackled by several researchers (Himaga et al., 2002), (Fang et al., 2003) , (Echevarría et al., 2004), (Chaudhuri et al., 1989). The preprocessing method proposed in this paper pursues the improvement of the illumination and contrast characteristics of the images by using information of different color

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spaces. In the next sections the proposed method is explained, the experimental results are shown and our main conclusions are offered.

2 DESCRIPTION OF THE MEDICAL PROBLEM

The data base used in this research work consists of 28 high resolution images. These images have been acquired in the Hospital Universitario de Canarias with a Canon D5 camera.

A retinography of our data base is shown in figure 1. Its different structures and parts are marked.

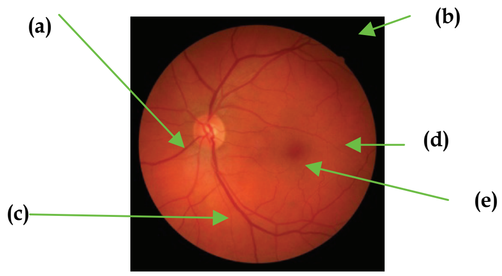

Figure 1: Parts of a retinography: (a) Papilla or optic Nerve Head (ONH), (b) Empty zone, (c) Blood vessels, (d) Retina, (e) Macula.

The excavation of papilla of optic nerve is the lightest zone inside the ONH. There are no nerve fibers in this zone. A big excavation of papilla involves a loss of nerve fibers and is sign of a glaucomatous papilla. Therefore, the automatic detection of this region can be helpful for the medical diagnosis process.

3 DESCRIPTION OF THE PROPOSED PREPROCESSING METHOD

3.1 Step 1: Scaling of the RGB Histogram

A narrow histogram produces low contrast images, independently of the image luminosity. A simple manner to develop contrast enhancement is to increase the histogram's dynamic range. The scaling of the histogram preserves the shape of the histogram and does not increase the background noise.

The RGB histograms of the retinographies (see figure 2, red) present a narrow distribution for G and B components (with a low average) and a wider distribution for the R.

Histograms' bimodality is clearly appreciated. The lower part represents the empty zone and the upper part corresponds to the ocular globe. Therefore, it is necessary the elimination of the distribution corresponding to the empty zone before expanding the histogram by the left side.

Once bimodality correction has been developed on the original histogram, a new histogram is obtained. We denote it as *a*. The scaling process is carried out as shown in equation 1, where *min* is the value n2, *max* is the percentile 99, (2^B-1) is the number of levels of the desired range (255 in our case) and *b* is the resultant histogram after the scaling procedure. Figure 2 shows the result of the scaling of the RGB histograms. It can be observed how each distribution is now wider.

$$b[m,n] = (2^B - 1) \cdot \frac{a[m,n] - \min}{\max - \min} \tag{1}$$

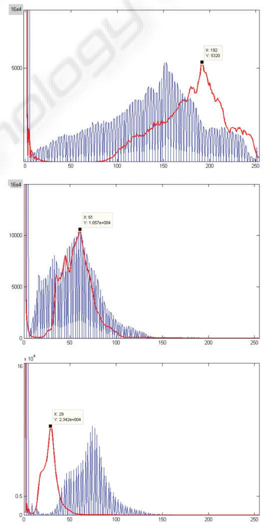

Figure 2: Original histogram (red) and scaled histogram (blue) of R, G and B components.

3.2 Step 2: Luminance Equalization in YIQ Space

The aim of this step is the equalization of the image luminance (to enhance the contrast and brightness of the image) without loss of color information. As result of this operation the blood vessels will be better defined in the three RGB components.

In the YIQ color space all the information about the image luminance is concentrated in Y component Therefore, an initial conversion from

RGB to YIQ is required and the Y component must be extracted. The luminance equalization is carried out through an adaptive equalization procedure.

Finally, the image is composed again in the YIQ space and converted to the RGB color space.

3.3 Step 3: Illumination Correction

The studied retinographies present illumination inhomogeneities. The illumination growths slowly from the borders to the center producing dark areas near the border.

For the tackled problem in this paper, images for calibration purposes have not been acquired. Therefore, the illumination correction must be done through a posteriori estimation. According to (Young et al., 1998), if I(x,y) is an image with illumination inhomogeneities, LP is a low pass filter and c a constant, the image after the illumination correction $I_c(x,y)$ will be the result of applying equation2.

$$I_c(x,y) = I(x,y) - LP\{I(x,y)\} + c \qquad (2)$$

Such formula can be implemented by separable kernel filters (one for rows and the other for columns). The low pass filter is calculated as the mean of every row or column and the constant to be added is the total average of the image (scalar) M, as it is shown in equation 3.

$$\begin{aligned} M &= mean(I(x,y)) \\ IR &= I - CR + M \\ IC &= IR - CC + M \end{aligned} \qquad (3)$$

where M represents the scalar average of a component, CR is an image in which every column is substituted by the mean of the column and CC an image in which ever row is substituted by its mean. Although order is not important, we have done in first place the correction by columns and then by rows for each component RGB.

A modification to the application of equation 3 on each image component must be done because some results have shown an illumination overcorrection. There are outstanding brighter zones in the retinographies (the ONH zone, as example). For these zones the row and column averages will be considerably higher than for the rest of zones of the image. The final illumination correction method develops a double process on the image, as shown in figure 3:

- Sub-process A: apply equation 3 on the image previously prepared as explained in the last subsection, to avoid overcorrection. A global illumination correction is obtained without considering the influence of the high illuminated zones.

- Sub-process B: apply equation 3 on the image without previous preparation. Therefore, an image with illumination overcorrection is obtained.

The last operation is the combination of the obtained images in both sub-processes: pixels of the high illuminated zones are extracted from the image of sub-process B; the other pixels are extracted from the image of sub-process A.

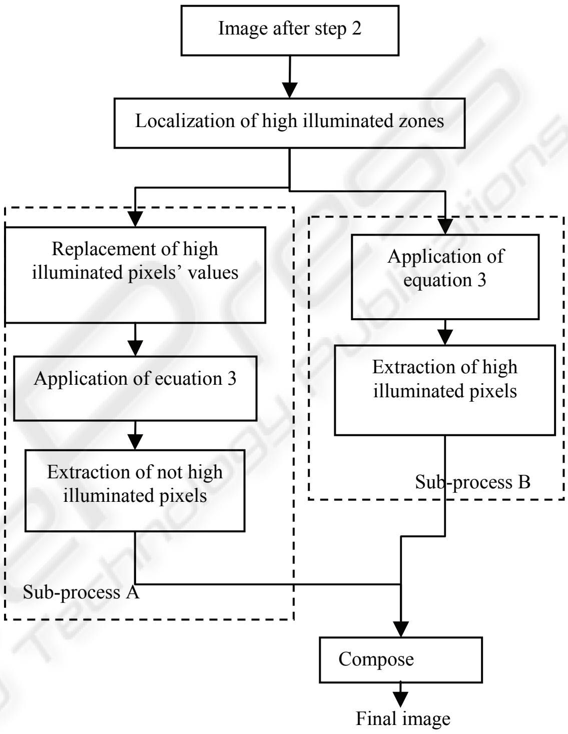

Figure 3: Complete illumination correction procedure (step 3).

4 EXPERIMENTAL RESULTS

The experimental results obtained with the proposed preprocessing method for retinographies are offered in figure 4. The figure shows the results corresponding to 8 retinographies of the data base of the Hospital Universitario de Canarias.

5 CONCLUSIONS

The application of image processing techniques on the retinography analysis is an increasing research field. Different techniques have been studied and developed, but these techniques are not automated and they normally require the user intervention. The work presented in this paper is part of a research project developed in collaboration with the Hospital Universitario de Canarias. The main objective of the project is the design of an automated software system for the delimitation of the ONH and for the differentiation of superimposed structures (arteries, vessels, and so on).

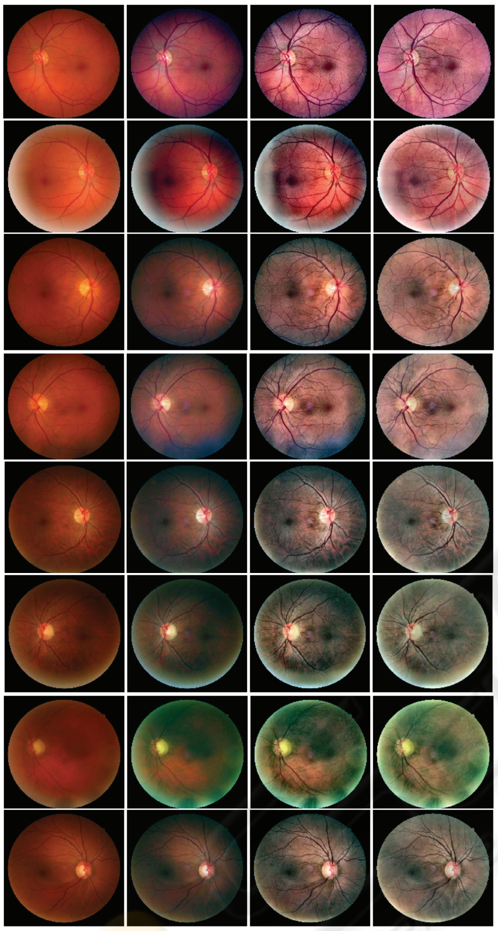

Figure 4: Experimental results. From left to right: original image, image after step 1, image after step 2, image after step 3.

Due to the difficulties presented by the retinographies it is essential to carry out a preprocessing stage, in order to improve the image before developing segmentation of the different regions of interest. This enhancement process has been the core of this paper.

The proposed preprocessing method comprises three steps: 1) scaling of the RGB histogram (improvement of the image information), 2) luminance equalization in YIQ color space (contrast enhancement without loss of color information), and 3) illumination correction. As shown in the experimental results, the preprocessing method develops an important enhancement of the main structures contained in the image. This will considerably allow designing efficient segmentation algorithms.

Our future research work will be oriented to the design of automated and efficient segmentation methods to be applied on the preprocessed images obtained in this work.

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