Optic Disc Approximation using an Ensemble of Processing Methods

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***Abstract* - This paper proposes a simple algorithm that can be used for the detection of the optic disc in retinal fundus images without human intervention. The original image goes through preprocessing to remove noise and to account for poorly taken photographs from the images. Optical disc detection involves segmentation of the preprocessed image through iterative thresholding of the green channel of the input image. The segmented image is further filtered using a series of methods such as histogram analysis and morphological operations such as erosion and dilations and other techniques. This developed technique has been tested image database obtained from Kasturba Medical College (75 images).For optic disc detection, we achieved an accuracy of 90.5% from the database obtained from Kasturba Medical Hospital, Manipal.**

Key Words: Optic disc, iterative thresholding, hough transform.

I. INTRODUCTION

Fundus photographs are the ocular documentation that depicts a clear representation of the patient's retina. These photographs are often used for detecting anomalies and allows doctors to monitor the progression of a disease affecting the eye. It is vital for diseases such as macular degeneration in the form of macular edema or macular holes, glaucoma, diabetic retinopathy, choroid detachment and many others.

Diabetes is a growing problem throughout the globe and especially in India. According to the International Diabetes Federation (IDF), India has the largest number of patients suffering from diabetes. There has been a constant rise in the number of diabetic patients in India over the past decade. Current studies and surveys and other statistics put the number of diabetics in the country at about 70 million.

Diabetes is a degenerative disease and over time, it has a profound effect on the eye. Many eye diseases can be attributed to it. Diabetic macular edema is one such disease. It leads to the weakening or leakage of the tiny blood vessels present in the macular region as a result of which the central part of the retina swells and this can a cause-impaired vision. Diabetic retinopathy is another example. It damages the small blood vessels in the retina; the consequence of this is poor blood circulation. This can also eventually lead to loss of sight as it causes tissue death due to the lack of oxygen supplied to the tissues.

The biggest problem with retinal tissue death is that once it dies it can never grow back. It is also possible for poor circulation to cause the development of scar tissue, which grow on the retina's surface.

The primary regions of interest in the eye are the optical disc, the center of the macula (called the fovea) and exudates, which exist in the form of bright yellow regions in the retina. In order to automate the detection of these features, their localization is of primary importance.

Overall automation of retinal feature detection is fundamentally dependent on the efficient localization of the optic disc. Through the optical disc, various conclusions can be drawn, namely diabetic maculopathy and glaucoma whose detection can be automated. Exudates also play a vital role in finding the severity of macular degeneration. They are mainly concentrated in the fovea region of the retina.

II. RELATED WORK

Localization of the retinal Optic Disc has been a very popular field of research over the past decade and different researchers have come up with different methodologies to do the same. S. Sekhar et al. states that the Optic disc is more or less the brightest region in the retinal images, and this property can be used to detect a localized region of high intensity pixels which can then be used to identify the possible optic disc locations. C. Sinthanayothin et al. Presents a method that involves the discovery of the location of the optic disc by detecting the region in the image with the highest contrast (intensity wise). A method is also presented for the detection of the fovea. It states that the location of the optic disc can be used to roughly detect the location of the fovea. The macula is usually present in a region that is at an approximately fixed. The window was chosen to be at a distance of about 2.5 times the Optic disc diameter from the Optic disc. They made use of a template-matching algorithm, choosing a Gaussian blob as their template. They defined the search window as aforementioned and ran the template over this window searching for any matches. Siddalingaswamy P.C. and Gopalkrishna Prabhu K. used the method of iterative thresholding to estimate the threshold for identifying the optic disc. Devika Ghodse and Dr. Bormane proposed a method to estimate the threshold of the optic disc by

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making use of the green channel histogram of the fundus image. The method used an approximation of the area occupied by optic disc in most retinal images. On applying this technique, bright regions called clusters are detected. All of these clusters represent possible optic disc regions.

III. PREPROCESSING

Preprocessing is generally done to eliminate the effect of noise and raise the suppressed features in an image. Therefore, techniques such as Fourier transforms, partitioning and channel segmentation are generally applied before feature extraction.

A. Green Channel Extraction

An RGB image can be divided into 3 atomic channels namely Red, Green and Blue. The green channel is chosen as the channel of choice when the fundus images are considered, primarily because contrast levels in the green channel tend to be higher than the red and blue channels. The highest contrast between the retinal background and the blood vessels was obtained for the green channel, on the other hand the red channel appeared to be overly saturated and the blue channel was rather dark.

The techniques applied on the image for Optic Disc detection are done in such a way that rotation invariance is maintained i.e. depending on the position of the camera during the image capture, the optic disc may appear on the left/right extremes or even in the center, in some cases. The proposed method ensures that the position of the optic disc in the image does not hinder its efficiency.

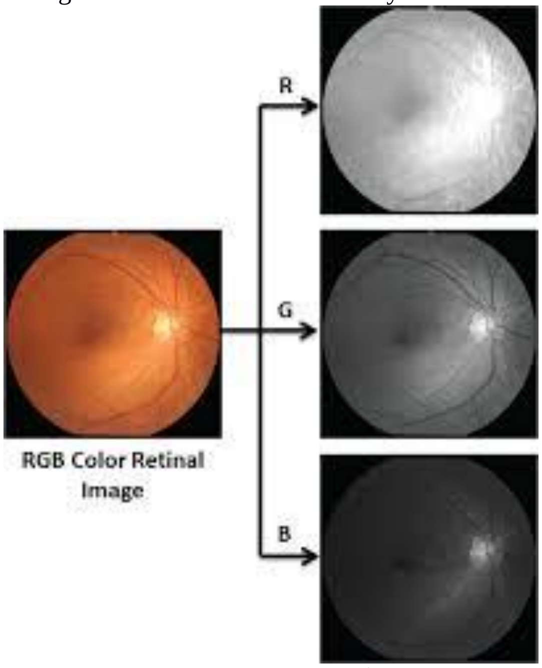

Figure 1. Original image along with the images from Red, Green and Blue Channels.

B. Contrast Equalization

Sometimes the images taken might be too dark or too bright because of faulty cameras, poor lighting or because of an error made by the technician. In order to neutralize the negative effects of these errors we performed contrast adaptive histogram equalization.

Adaptive Histogram equalization (AHE) is a method that is generally used to normalize and improve the contrast in images. This method differs from ordinary histogram equalization with respect to the region upon which the histogram is calculated. In Adaptive Histogram equalization, multiple histograms are calculated over predefined regions in the image. E.g. If the image is 256 x 256 in size, then it may be represented as a grid of 16 x 16 wherein each grid has a localized histogram. Therefore, through these histograms, the intensity values are normalized and distributed throughout the image.

Contrast Limiting and Adaptive Histogram Equalization takes AHE one-step further. In each localized region of the grid, contrast limiting is applied so as to counterbalance the effect of over-amplification of noise caused by AHE. Another point that can be stressed on is the fact that the histogram ‘bins’ of the localized region exceeding the limit, defined by the CLAHE method can be redistributed among the neighboring regions. However, in doing so, the problem of over-amplification may recur. Hence, CLAHE can be effectively thought of as an iterative method of clipping and redistribution for normalization of noisy, fundus images.

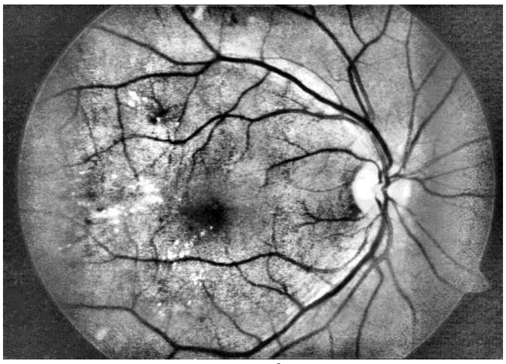

Figure 2. Image after CLAHE

IV. METHODOLOGY

The proposed method can be elaborated over a sequence of steps, which is defined in the subsections below

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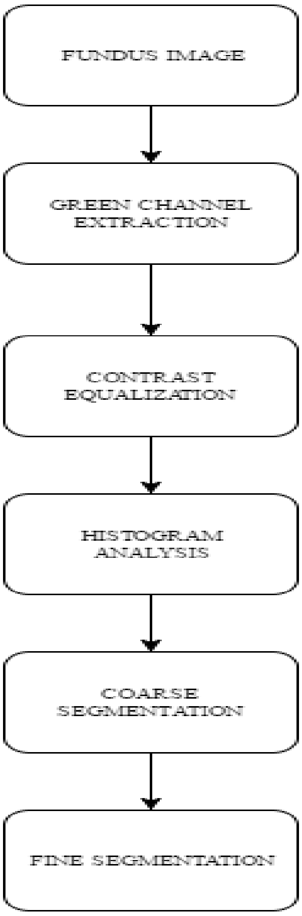

Figure 3. Methodology Flowchart

A. Histogram Analysis

A histogram is a graphical representation of the frequency count of each pixel corresponding to a particular intensity. Essentially, an image histogram can be correlated to the probability distribution function (PDF) of each pixel within the image.

In the case of Optic Disc detection in fundus images, we operate on the known fact that the intensity of the Optic Disc is usually the highest in the image. Therefore, by observing the histogram, we can effectively isolate the pixels that belong to the region in between the third quartile and the maximum intensity of the histogram. This helps us locate the brightest regions in the image. The histogram also plays a fundamental role in Image Thresholding, which is explained in the section below:

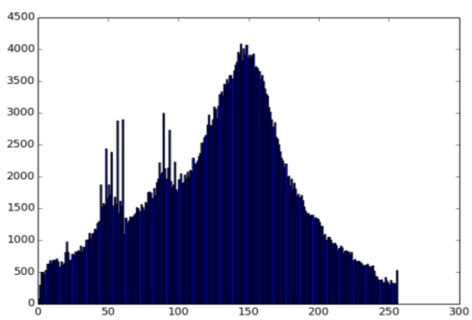

Figure 4. Histogram of image after applying CLAHE

B. Coarse Segmentation

The methods used for the identification of the Region Of Interest (ROI) include iterative thresholding, fundamental morphological operations such as erosion and dilation.

1) Iterative Thresholding:

Thresholding is a simple technique that belongs to a broader class of image segmentation algorithms. It is essentially used to create binary images from gray scale images by segmenting each pixel's intensity based on a cutoff called the threshold intensity i.e. if each pixel has an intensity $I_{i,\,j}$ wherein (i, j) is the spatial co-ordinate of the pixel on the image, then, thresholding can be defined as the value 'T' which segments pixels on the condition if $I_{i,\,j} < T$ or $I_{i,\,j} \geq T$. The result of the thresholding yields a binary image. Different Thresholding techniques are implemented based on the criterion used for selection of the Intensity parameter (T).

Iterative thresholding is a form of thresholding wherein the threshold parameter 'T' is changed with every iteration until an ideal threshold value is obtained. Initially, the nominal intensity value is chosen as the threshold intensity and depending on the distribution of pixels in the image, the threshold sways either to the left or to the right of the nominal value with each iteration.

In our method the threshold value is deduced from the histogram of the green channel image. The threshold value is set to the intensity at which only 25% of the pixels are above it. After obtaining this threshold value we threshold the image.

2) Elimination of false candidates:

Image Morphology or Mathematical Morphology is basically a theory that derives from various mathematical concepts such as set theory, lattice theory and topology. The methods mainly revolve around operations performed by taking a structuring element and probe this element throughout the image. Depending on the operators applied, morphology can be built upon fundamental operations such as Erosion, Dilation, Opening and Closing.

Erosion: The main idea is to iterate the structuring element throughout the image and the and therefore check for morphological inclusivity. Therefore, if 'E' were a Euclidian Space or an integer grid, and 'A', a binary image in 'E', then the erosion of the binary image 'A' by the structuring element 'B' is defined by:

$$A \ominus B = \{z \in E \mid B_z \subseteq A\} \quad (1)$$

Wherein, $B_z$is the translation vector given by:

$$B_z = \{b + z \mid b \in B\}, \forall\, z \in E \quad (2)$$

Dilation is mainly used for the expansion of shapes contained in the image and the restoration of detail after the erosion operation is applied onto the image. The spaces and holes that were formed during erosion in the binary image are filled by joining the nearest neighboring pixels. Mathematically, dilation can be expressed as:

$$A \oplus B = \{z \in E \mid (B^s)_z \cap A \neq \emptyset\} \quad (3)$$

Wherein, 'A' is the binary image, 'B' is the structuring element and B^s is the symmetry vector given by:

$$B^S = \{x \in E \mid -x \in B\} \quad (4)$$

In our method we first perform erosion to remove all small isolated blobs in the image thereby eliminating the unnecessary regions. This action is followed by dilation to compensate for the loss of the borders of bigger blobs that are possible candidates for being the optic disc.

3) Intensity retention:
A region of Interest is essentially a portion of the image that is extracted for observation and manipulation purposes. In the case of fundus images, the prime Region of Interest is the Optical Disc. Therefore, after the morphological operations are performed on the thresholded image, multiple patches tend to exist on the binary image. Since it is important to maintain the original intensities of the identified region of interest we AND both the thresholded image and the original green channel image.

Rules of AND in an 8 bit image where x is any intensity value ranging from 0-255:

255 & x: = x (5)

0 & x: = 0 (6)

Figure 5. Image after thresholding and the AND operation.

B. Fine Segmentation
The Circle Hough Transform is basically a variation of the Hough Transform algorithm and is mainly used for feature extraction and the detection of circles in images. This method employs a 'voting' procedure in order to localize the circle candidates in the Hough parameter space. An accumulator
matrix is initialized to reflect the two-dimensional co-ordinate space wherein each cell represents the spatial position of each pixel. It is primarily used for localization, as the Optical disc exists in a near-circular shape. Therefore, for every edge point (i, j) lying on the circle, the cells corresponding to the center of the circle are incremented. The equation of the circle is defined as:

$$(i-\alpha)^2 + (j-\beta)^2 = r^2 \quad (7)$$

Wherein, $(\alpha, \beta$ is the center of the circle and 'r' is the radius of the circle. For each possible value of $'\alpha'$ corresponding to the edge co-ordinates (i, j), all values of $'\beta'$ are obtained through equation (7). Hence, every center is stored as local maxima in the accumulator matrix and thereby the cells representing these centers depict the circles present in the image.

Although this algorithm is useful in detecting circles in a given image, multiple, unwarranted circles are also generated. In order to further filter out these undue circles, a rough estimate is used to localize the circles that are identifiable as potential candidates for the optical disc. The estimate is based on an experimental observation i.e. the approximate range between the minimum and maximum radius of the Optical Disc is known prior to the automation. This radius is obtained from the work of [7] according to whom the area of the optic disc in pixels is obtained from the formula: -

$Area_{OD}$ = (3.14 * imlen * imlen) / (4*8*7.33). (8)

The radius can then be obtained using the formula:
Radius = ($Area_{OD}$/3.14)^0.5. (9)

Here 'imlen' is the length of the image. After applying the hough circle transform we sometimes detect multiple circular regions to counter this the sum of intensities of each of the regions identified by the hough circle transform is calculated and the region with maximum intensity is considered to be the optic disc.

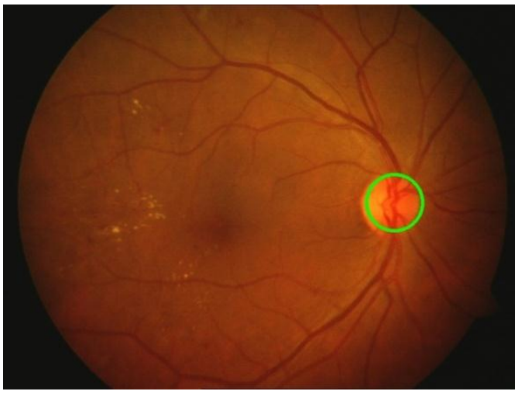

Figure 6. Final Image containing Optic disc center

V. RESULTS

Images listed under Kasturba Medical College (KMC) Database have been taken from the ophthalmology department of KMC, Manipal. The images had a lot of variety in terms of the position of the optic disc some had it on the left and some on the right and a few in the center. Some images also had exudates, some were extremely bright either due to the technicians fault or because of hemorrhages.

The language of choice was python 2.7 and the packages used were openCV 3.1, numpy and matplotlib. The algorithm was run on a system having 4 gigabytes of random access memory and an intel i5 processor. The time required for execution was found to be 0.0940 seconds per image which had a resolution of 480 x 360.

Table 1. Results

Serial Number	Dataset	Images	Accuracy
1.	KMC Manipal	75	90.5%

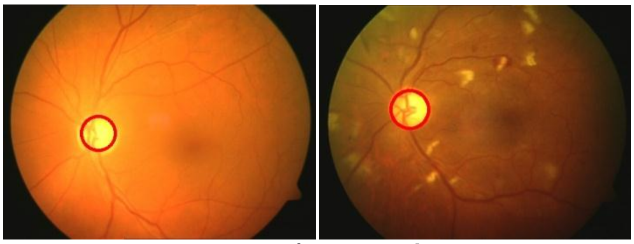

Figure 7. A few more results.

VI. CONCLUSION

The method presented on our paper is to automatically detect the optic disc in a retinal image and it has achieved an overall accuracy approximately equal to 90.5%.

Our results can improve by improving on the existing preprocessing techniques and implementing advanced preprocessing techniques for fundus images. We plan to further incorporate the detection of exudates in the retinal image in our paper. The detection of exudates is a crucial step in the detection of irregularities in the eye, which further help us in detecting diseases such as glaucoma and diabetes. This image processing technique provides an inexpensive and non-invasive way of detecting diseases in the eye.

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