Glaucoma Detection based on Phase Information of Fundus Images

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Abstract- This paper applies the process and knowledge of digital image processing for detection of Glaucoma using the phase information of the color fundus images. Glaucoma is one of the major causes of blindness, caused due to neuro-degeneration of the optic nerve of human eye. One of the most important characteristics of Glaucoma is decreased neuro-retinal rim area, affecting the peripheral vision loss. Color fundus image analysis has gained its importance in last few decades as it provides vital information regarding the severity of diabetic eye diseases. The fundus images are recognized as one of important document for the ophthalmologist for early detection of different pathologies and diagnosing of various eye diseases like Diabetic Retinopathy, Glaucoma and Cataract which occurs in the people of various age groups due to their modern life style. These diseases cause vision impairment and blindness due to diabetes, which occurs due to the elevation of glucose in blood. The proposed method discuses the method of detection of Glaucoma based on only phase information of color fundus images. The criteria for Glaucoma detection is based on evaluation of cup to disc ratio (CDR) obtained by multi-thresholding technique on processed image containing phase information. This kind of automatic detection can easily process a large number of fundus images obtained from mass screening in order to help eye specialist in early stages. In fact it will help to reduce the cost and increase the productivity and efficiency for ophthalmologists.

Keywords – Glaucoma, Fundus Image, Phase Information, Multi-thresholding, CDR.

I. INTRODUCTION

Glaucoma is a complication of diabetes and is a chief cause of blindness among people of various working age group. According to the World Health Organization, Glaucoma is the second leading cause of blindness (after cataract) in the world [1].The patients suffering from this retinal disorder might not feel a loss of vision until it became too severe, hence early diagnosis and well-timed treatment is essential to postpone or avert visual impair and even blindness. Color fundus images are exploited by ophthalmologists to study retinal diseases like Glaucoma and Diabetic Retinopathy (DR). The interior face of the eye comprising of retina, optic disc and fovea refers to fundus of eye, situated opposite to the lens. Glaucoma implies a group of conditions described by a progressive optic neuropathy leading to visual field alterations. It causes permanent loss of the peripheral field which can be established by a visual field test. The normal vision and the vision affected by the Glaucoma is shown in Figure1.1 and Figure1.2 respectively[2]. Sometimes, Glaucoma is also termed as the 'creeping thief of sight' as it attacks without giving recognizable symptoms. Glaucoma can crop up in people of diverse age groups from babies to adults. It is established that up to 1 million Indians, age 40 and over, have Glaucoma [1]. Raised intra-ocular pressure (IOP) is categorized as a risk factor for Glaucoma. The IOP compress the nerve fibers in the form of mechanical pressure when they exit from the optic nerve to the visual cortex inside the brain. This compressive force is responsible for the nerves to die off. The overall decay of the number of nerve fibers is more in the peripheral region than the macular, which triggers peripheral vision loss in case of Glaucoma [3]. It triggers typical structural changes of the optic nerve head (ONH) and the nerve fiber layer disturbing the visual field of the subject. The structural changes are the product of the slowly shrinking neuro-retinal rim establishing a degeneration of axons and astrocytes of the optic nerve as shown in Figure 1.3[3]. Early detection of Glaucoma using fundus image analysis can prevent loss of vision. Therefore, it create a pressure to fulfill the general objective of creating a frame work to process fundus images for detection of Glaucoma which can lead to visual impairment or even blindness if not detected at early stage. In addition, this kind of framework could aid ophthalmologists to increase their productivity, efficiency as well as cost effective to identify patients for early treatment to prevent or delay visual loss

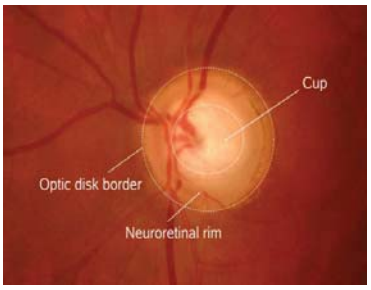
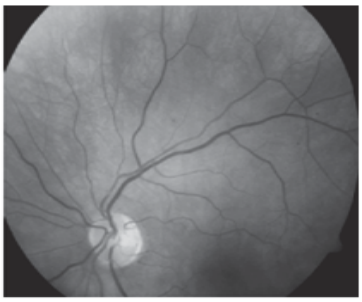


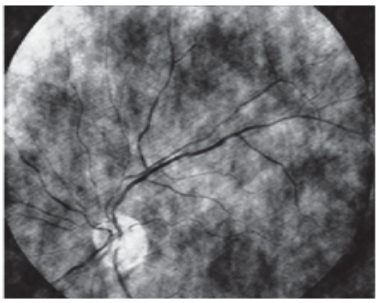
Fig. 1.1: Normal vision [2] Fig.1.2: Vision affected by glaucoma [2] Fig. 1.3: Major structures of the ONH[3].

This paper describes an effective framework for timely detection of Glaucoma using phase information of color fundus images. The criteria for Glaucoma detection is based on evaluation of cup to disc ratio (CDR), obtained by multi-thresholding technique on processed image containing only phase information. The remaining part of the paper is as follows. The literature review is presented in section II. Section III describes the proposed approach and result of the experiment. Finally conclusion is presented in section IV.

II. LITERATURE REVIEW

Literature reports several digital image processing techniques for the automatic detection of Glaucoma using fundus Images. These techniques can be classified mainly in two groups, one is based on segmentation of retinal objects and other is based on classification[4][5]. The first approach requires segmentation of main retinal structures which are affected by Glaucoma. In this approach, some important parameter evaluation is done, most commonly Cup to Disc Ratio (CDR) which is defined as the ratio of cup diameter to that of optic disc diameter measured vertically to level the image as normal or glaucomatous. The subject is considered suspicious if this ratio exceeds 0.5[4]. Another technique which avoids CDR measurement by segmentation is feature based. This technique uses the features of whole image or of ROI, which are extracted and feed into various classifiers for Glaucoma screening [6]. In the literature many techniques have been used to automatically detect the position of the optic disc in retinal images. Sinthanayothin et al. [7] located the optic disc by identifying the area with the highest variation in intensity of adjacent pixels. W. Ruengkitpinyo et al.[8] has used the classifier method where SVM is used for Glaucoma screening. A. Salam et al. [9] reports the computation of texture features from fundus image and use of KNN classifier for its detection. T. Khalil et al. [10] in his review paper discusses various machine learning techniques like ID3 algorithm for decision tree, Fuzzy Logic, Neural Network, Naive Bayes classifier, k- nearest neighbor and active counter methods for detection and prediction of Glaucoma. Z. Xiao et al.[11] discusses the importance of phase information for analysis of Diabetic Retinopathy (DR) using fundus image processing by stating the fact that traditional techniques uses the gradient information to depict the image. The gradient information is very sensitive to noise, which varies with image contrast and brightness whereas phase information is invariant to contrast and brightness, having good anti-noise ability. Besides this, phase information is very useful for depicting image in addition to the fact that it is consistent with human visual system (HVS) characteristics. Oppenheim and Lim gave the classical proof [12], that if we take the Fourier transform of two different images and add phase information part of one with amplitude information part of another image then resulting new image obtained after inverse Fourier transform will be consistent with the first image. Although obtained new image will be somewhat blurred, it will be consistent with the image giving the phase information and we can see almost nothing about another one. Figure 2.1 demonstrates this fact.





(a) (b) (c)

Figure 2.1: Demonstration of the phase importance of phase information [11]12].

(a) is image giving phase information, (b) is image giving amplitude information, and (c) is formed image by amplitude of (b) and phase of (a).

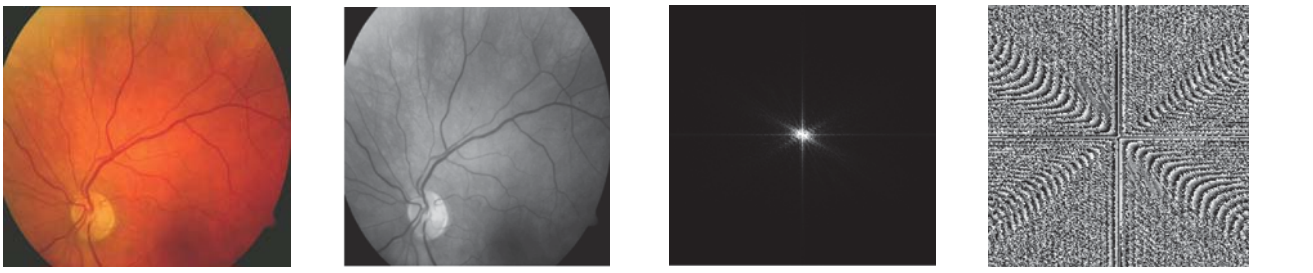
III. Experiment and Result

3.1 Explanation of the experiment:

Two images namely a color fundus image [13] and a color Lena image (downloaded from https://en.wikipedia.org/wiki/Lenna, most commonly used standard image in many image processing experiments) are considered for performing the simulation in order to first verify the importance of phase information in the images as explained in [11][12] . Later on, only phase information of fundus images (normal and glaucomatous publically available on http://www.optic-disc.org/library) were used for glaucoma detection based on evaluation of CDR using multi-thresholding technique. Thus the proposed method for glaucoma detection can be explained in three steps: (1) Extraction of phase information from input color fundus image (2) Segmentation of optic cup and disc from preprocessed image based on multi thresholding technique (3) Classification based on evaluation of CDR.

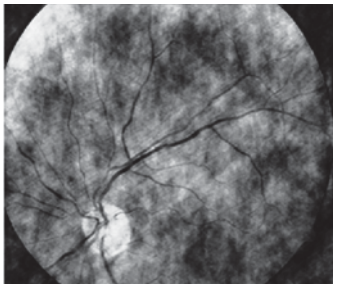
3.2 Importance of Phase information in the image:

First of all, a color fundus image is converted into its corresponding gray image and then Fast Fourier transform (FFT) is applied to obtain its magnitude and phase information. The same is done to second image, in this case it is a Lena image. After that, the phase information of gray fundus image is combined to that of magnitude information of gray Lena image and then Inverse FFT is applied to obtain a new image. The obtained new image, though somewhat blurry but is found to be consistent with that of the first gray fundus image. When inverse FFT is applied to get a another new image by considering the phase information of gray Lena image and magnitude information of gray fundus image, then again it is found that the new image is consistent with the phase information and there is no much evidence of magnitude information. The step wise results of this simulation is shown in Figure.3.1 from (a) to (h). Thus this experiment demonstrates that only phase information of fundus image can be exploited for fundus image analysis for diabetic eye diseases like Glaucoma. One of the advantage of using phase information only is that it will need lesser memory for its transmission and processing, besides eliminating the need of pre-processing like illumination correction. It is observed that the phase information is so important in image perception, that breakthrough can be achieved in the Glaucoma objective analysis using image processing techniques based on phase information which is consistent with HVS.



(a) Fundus Image **(b)** Gray image of (a) **(c)** amplitude information of (b) **(d)** phase information of (b)

(e) Lena Image | **(f)** Gray image of (e) | **(e)** amplitude information of (e) | **(f)** phase information of (e)



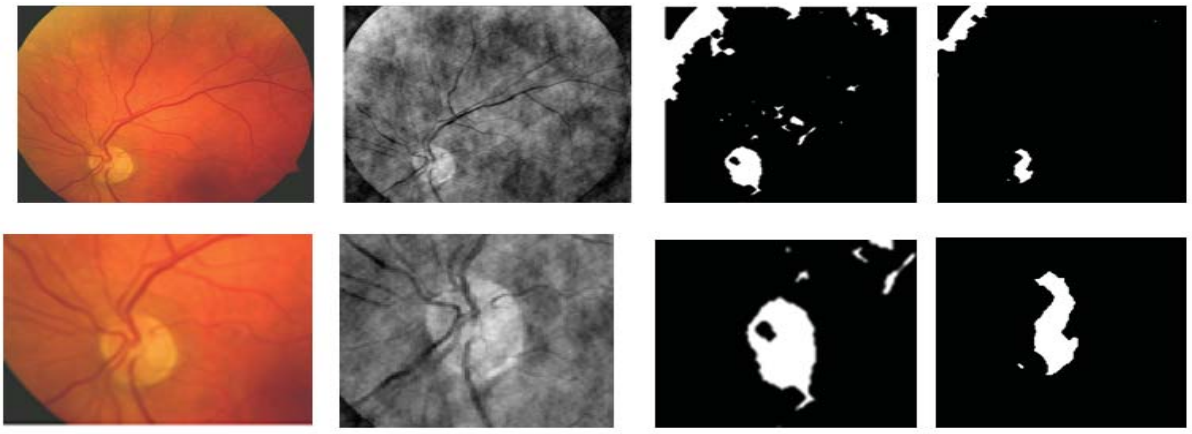
(g) is formed image by amplitude of (b) and phase of (e).

(h) is formed image by amplitude of (e) and phase of (b).

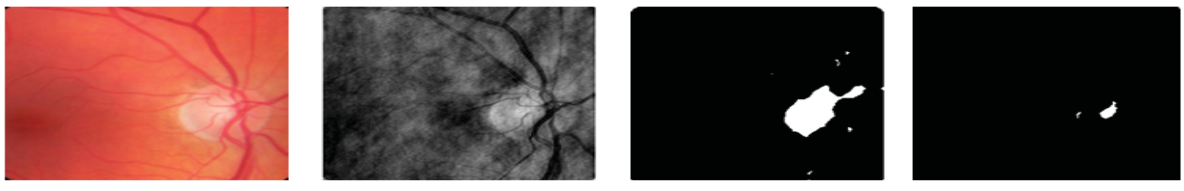
Fig.3.1 showing the results of the experiment, demonstrating the importance of phase information in image.

3.3 Fundus image segmentation using phase information

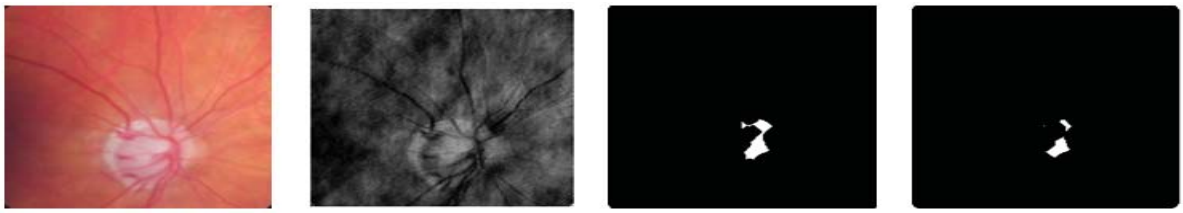
In this work, multi-thresholding technique is applied on the obtained image which has only phase information in order to detect cup and disc. The multi- thresholding as the name suggest it uses two threshold levels. This is employed in detection of cup and disc of fundus image. Here advantage of the property that cup is the brighter region of fundus image is exploited. So, a small threshold level is kept in order to detect the disk and then increased threshold to detect the cup, as the cup is brightest region in the disc. Hence, cup and disc was segmented using said technique as shown in Figure 3.2.



(i) Normal fundus image (a) With phase information (b) Disc (c) Cup



(ii) Normal fundus image (a) With phase information (b) Disc (c) Cup



(i) Glaucomatous image (a) With phase information (b) Disc (c) Cup

Fig. 3.2: Results of segmentation using multi-thresholding technique.

3.4 Detection of Glaucoma using Cup to Disk Ratio (CDR)

The hallmark of glaucomatous progression is cupping of the optic nerve head. Therefore, CDR is considered as an important parameter to detect Glaucoma. The block diagram of proposed method is shown in Figure 3.3, where the CDR threshold value is fixed as 0.465 to determine Glaucoma Risk Index (GRI).

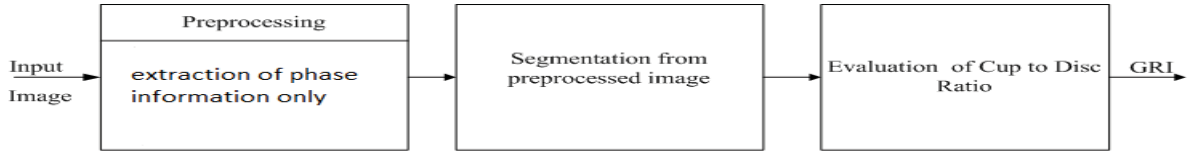


Fig.3.3: Processing pipeline for detection of glaucoma.

The phase information is extracted from the input fundus image for segmentation of cup and disc using multi thresholding technique. It is found that the evaluated CDR value correctly classifies both the normal and glaucomatous image. Thus, the proposed method can be beneficial in a mass screening of fundus images for Glaucoma classification at early stages.

IV.CONCLUSION

In this paper, an automatic Glaucoma detection method is developed which exploits only phase information of fundus image. The classification is based on evaluation of CDR using Mutli-thresholding technique. The proposed method is able to classify normal and glaucomatous images correctly. Thus, this method of detection has wide scope for the initial screening of Glaucoma where only phase information is available, in today's fast changing world which demands for automated and fairly accurate diagnosis processes.

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