IJCTA, 8(3), 2015, pp. 1147-1152

Glaucoma Detection by Image Fusion from Fundus Color Retinal Images: A Review

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Abstract: Glaucoma is a group of ocular diseases resulting serious visual consequences. The common traits are high eye pressure, damage to the Optic Nerve Head and gradual vision loss. It affects peripheral vision and leads to permanent blindness if not detected in early stages. Various medical imaging techniques are used to diagnose glaucoma by ophthalmologists like Scanning Laser Ophthalmoscope (SLO) and Optical Coherence Tomography OCT. These techniques are costly and time consuming. The presented review article here discusses the different automated techniques developed for the glaucoma detection. Here we discuss the automated method which is independent of image quality and invariant to noise to screen glaucoma.

Keywords: Glaucoma, fundus images, image fusion

1. INTRODUCTION

Glaucoma is an ocular disorder that results in damage of optic nerve.It is often associated with increased fluid pressure in the eye (intraocular pressure). Glaucoma can permanently damage vision in the affected eye(s), if left untreated. First it decreases peripheral vision (reduces the visual field), and then potentially leading to blindness. Worldwide, glaucoma is the second-leading cause of irreversible blindness. In fact, around 6 million individuals are blind in both eyes from this disease.

Early detection and treatment of retinal eye diseases is critical to avoid preventable vision loss. In the Conventional methods, eye diseases are identified by manual observations, where the Patients are imaged using a fundus camera. Later ophthalmologists apply image processing techniques to interpret these images and diagnose results. If specific abnormalities are observed, ophthalmologists may further perform Fluoresce in Angiography or Optical Coherence Tomography (OCT) for further investigation. These diagnostic and interpretation techniques are time consuming and invasive [1].

As there is no cure for Glaucoma, but its early detection helps in proper treatment may prevent the permanent vision loss. The manual based diagnostic process is costly, time consuming and may prone to error. So, many efforts and researches have been made for automatic detection of Glaucoma at an early stage.

2. CLINICAL TESTS

Glaucoma is a group of ocular diseases in which the optic nerve, connects eye to brain, is damaged by the pressure of the fluid inside the eye. There are three main clinical tests usually carried out to identify glaucoma.

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- In the first one, the optometrist checks the nerve at the back of eye using a special torch called an ophthalmoscope, or a machine called a slit lamp. They may also image the nerve which will be useful for future visits, to help them to diagnose.
- The second test the optometrist measures the pressure inside the eye using an instrument called a tonometer.
- The third test, the optometrist tests wide subject's visual field – how far subject can see around, when subject is looking straight ahead.

To suspect the Glaucoma UK's National Institute of Health and Clinical Excellence (NICE) has framed the guidelines. According to them the tests offered for suspecting Glaucoma or Ocular Hypertension are eye pressure test (Tonometry), corneal thickness (Pachymetry), Gonioscopy, visual field test (Perimetry) and optic nerve head (ONH) appearance [1]. Glaucoma is suspected if intra ocular pressure (IOP) value exceeds 21Hg. Fig 1. Shows the image of normal eye and eye with glaucoma.

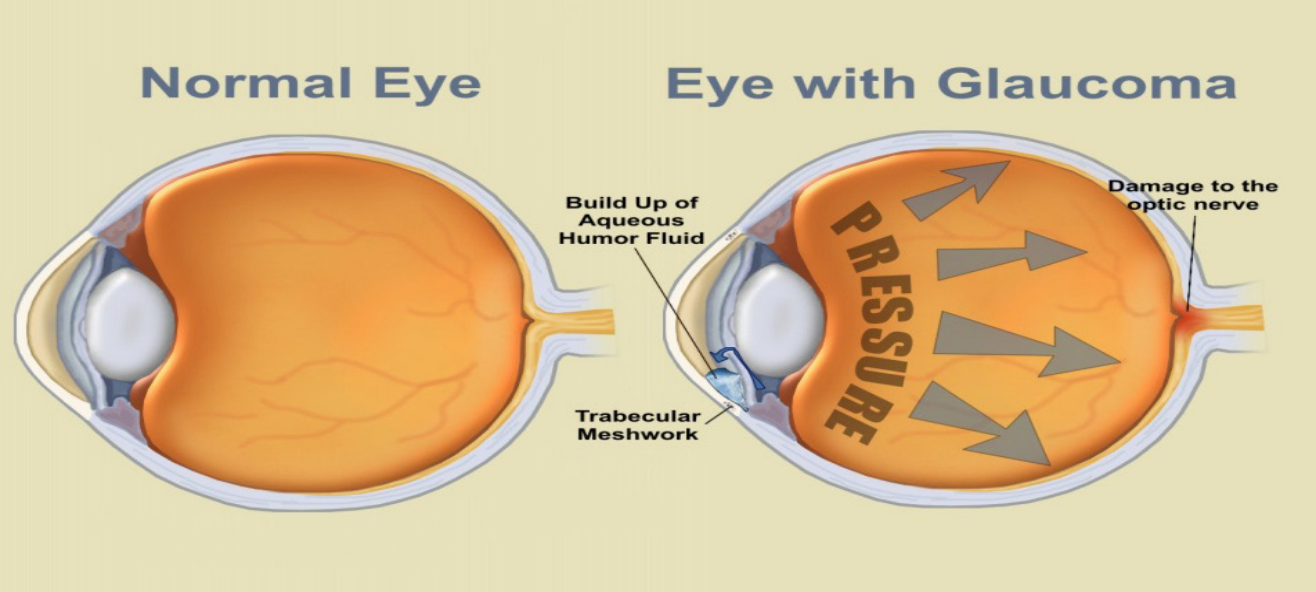

Figure 1: Image of normal eye and eye with glaucoma

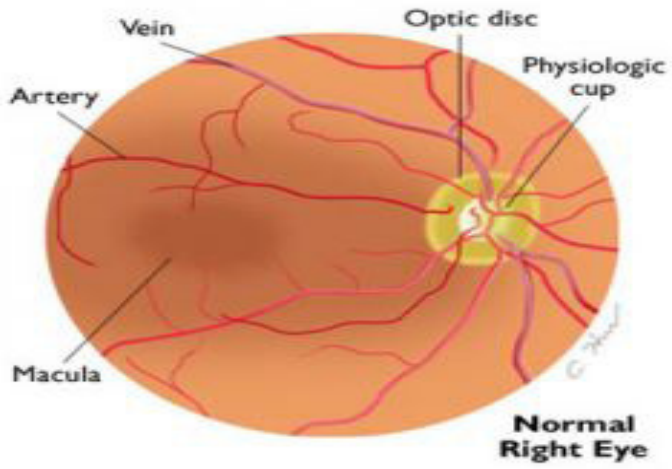

Figure 2: Left retinal color fundus image.

3. IMPORTANT FEATURES OF RETINAL FUNDUS IMAGE

Fundus word is derived from Latin, which mainly refers to a portion of organ opposite from its opening. Fundus image of an eye is the photograph of the interior surface of the eye. Mainly includes retinal blood vessels, macula, fovea, optic disk and optic cup as shown in Fig. 2. The various factors from the image needed to be quantitatively analyzed to determine glaucoma disorder. Optic disk size, cup to disk ratio, rim disk ratio and retinal nerve fiber layer height (RNFLH) are some important factors in the evaluation of optic nerve head (ONH) and retinal nerve fiber layer (RNFL). Since glaucoma affects optic disk and optic cup by changing cup to disk ratio and rim to disk ratio therefore proper segmentation of these features is essential for glaucoma detection [9].

4. TECHNIQUES INVOLVED

One of the major reasons people lose significant vision due to glaucoma is mainly because they present too late in the course of their disease. Despite of technological advances in disease diagnosis, according to the U.S. Preventive Services Task Force there is insufficient evidence for effective glaucoma screening strategies in 2005 [3].

Glaucoma is among the most common causes of permanent blindness in human. Because the initial symptoms are not evident, mass screening assists early diagnosis in the vast population. Such mass screening requires an automated diagnosis technique [6]. The present clinical methods for Glaucoma detection mainly include manual observations and are sometimes invasive; therefore the development of automated techniques for the extraction of features related to Glaucoma aids their diagnosis in a time effective and non-invasive manner. Glaucoma can permanently cease the eye sight but its diagnosis and treatment at earlier stage can slow down the progression of the disease [1].

With the detection and evaluation of some parts of the retina, mainly the optic disc (or optic papilla), the excavation, and the blood vessels located within it (vascular bundle) are helpful in the detection of glaucoma. The characteristics most frequently analyzed are the measurement of the cup/disc ratio and the neuro retinal rim thickness. The feature extraction method relies only on the analysis of morphological alterations that can be detected within the optic disc, even when the size of the excavation is in the initial stage of glaucoma [7].

Different ophthalmic imaging technologies are used to capture images including Fundus images, Confocal Scanning Laser Tomography (CSLT), Optic Coherence Tomography (OCT) for detection and prediction of glaucoma [5].Recently, digital imaging, such as scanning laser tomography, scanning laser polarimetry and optical coherence tomography, is used as a clinical tool to for the assessment of the optic disc and nerve fiber layer in glaucoma detection. For quantitative analysis neural networks and fuzzy logic, the two complementary technologies are applied on Stratus OCT data to detect glaucoma [2].

Several automated glaucoma detection systems were thoroughly analyzed in this study. A detailed literature survey different imaging techniques and automated glaucoma diagnosis systems used for testing and detecting the glaucoma. The information extracted from the analysis of digital images of eye can be used for automated detection of glaucoma.

There is some segmentation and non-segmentation based automatic methods used to extract the features from the retinal structures that reflect changes due to Glaucoma. Since most of segmentation based need Optic nerve hypoplasia (ONH) analysis, therefore, the existing methods for analysis of the Glaucoma are related to extraction of ONH and its anatomical structures [1].

Several proposed automation procedures consists of preprocessing of images as a basic step for the

feature extraction of the retina. The hyper analytic wavelet transformation (HWT) is used for statistical features extraction from fundus images. The features are then classified by a Support Vector Machine (SVM) with a radial basis function (RBF) kernel. To overcome premature convergence, a Group Search Optimizer (GSO) random searching (ranging) and are a scanning behavior (around the optima) are embedded within the Particle Swarm Optimization (PSO) framework [6].

Some automated glaucoma diagnosis systems have used higher order spectra (HOS) cumulants extracted from Radon transform (RT) applied on digital fundus images. In this work, the images can be classified into three classes: normal, mild glaucoma and moderate/severe glaucoma. Here the 3rd order HOS cumulant features are subjected to linear discriminant analysis (LDA) and then these clinically significant linear discriminant (LD) features are fed to the support vector machine (SVM) and Naïve Bayesian (NB) classifiers for automated diagnosis. The proposed system has detected the early glaucoma stage with an average accuracy of 84.72% [4].

An automated image processing approach for detection of glaucoma is a diagnostic tool to help ophthalmologist in mass screening of glaucoma suspects. The approach is based on the segmentation of optic disk and the optic cup and computing the cup-to-disc ratio. Further, Hough Transform is used to calculate the radius of optic disk and optic cup. The vertical cup to disk ratio is used as a parameter for identification of glaucoma symptoms in the fundus image [9].

Always a computer plays a central role in the automated detection of Glaucoma. As an attempt a computerized risk assessment system for glaucoma detection was developed. The system analyzes the patients' clinical information, and the performances of the nerve fiber layer defects (NFLDs) detection. Later the glaucoma risk assessment were compared. The clinical data mainly included are the systemic data, ophthalmologic data, and right and left retinal images. Here a Glaucoma risk assessment algorithm was developed using machine learning technique, artificial neural network, radial basis function (RBF) network, k-nearest neighbor algorithm, and support vector machine. But glaucoma risk assessment using this method was not evaluated [10].

Several approaches are developed for automatic calculation of cup to disc ratio using accurate detection of disc and cup, and quantitative determination of their areas in retinal fundus images to diagnose glaucoma [11]. The medical techniques used by ophthalmologists like HRT and OCT is costly and time consuming. Hence there was a need to develop automatic system with a aid of computer system which can detect glaucoma efficiently and in less span of time. Optic disk and optic cup are two primary features that help in diagnosing glaucoma. By developing a proper segmentation algorithm for segmenting optic disk and optic cup helps in detecting the disorder. An adaptive threshold based method was developed which is independent of image quality and invariant to noise is used to segment optic disk, optic cup, Neuroretinal rim and cup to disk ratio is calculated to screen glaucoma. Another ocular parameter, rim to disk ratio is also considered in combination with CDR which gives more reliability in determining glaucoma and makes the system more robust [12].

Current methods for the automatic detection of glaucoma have difficulties in segmenting the disc and cup. Segmentation is a crucial step in automatic analysis that determines the accuracy of the results. Most of the techniques discussed have used Fundus images. Fundus images are simple digital images that do not provide internal details of eye. An OCT scan can detect the early signs of glaucoma, detached retinas and other eye disorders. This scan allows optometrist to visualize the fine details in the images of the retina, enabling them to accurately detect, monitor and control changes to the retina. This procedure is currently the only one imaging technique that shows in-depth images of the eyes internal structures. But this technique is very costly.

So by using the fundus color images at different angles and developing an algorithm based on image fusion techniques enables the system to calculate the like radius of optic disk and optic cup, height of the optic nerve and neuroretinal rim. This automated method makes the system which is independent of image quality and invariant to noise to screen glaucoma and more reliable.

5. CONCLUSION

Glaucoma permanently ceases eye sight .There are no such noticeable symptoms that able to detect the glaucoma in the early stage. In this paper work has been done to identify the glaucoma in the early stages. The following conclusion can be drawn:

- Many automated detection techniques have been proposed for the glaucoma detection. Most of the techniques have used fundus images and OCT images.
- Current methods for the automatic detection of glaucoma are based on segmenting the disc and cup which is the crucial step.

The system using the fundus color images at different angles and applying the image fusion techniques to calculate the parameters like radius of optic disk and optic cup, height of the optic nerve and neuroretinal rim helps in the automated detection of glaucoma in its early stage. Early detection helps in recovery of glaucoma patients.

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