International Journal of Futuristic Research Evaluation in Engineering (IJFREE)
Volume: 2 Issue: 4 August 2020

A Review Paper on an Automatic Localization of Optic Disc and Segmentation Approaches for Glaucoma Diagnosis

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Abstract: *Glaucoma is a leading cause of stable blindness. Retinal fundus image examination is necessary for early detection of Glaucoma. In order to identify the existence of Glaucoma, the ophthalmologists conclude the localization of optic disc in the fundus image. This review paper is a study of current techniques and segmentation approaches to automatically detect the optic disc, which is one of the most main medical features of the fundus image. The idea behind this paper is to provide overview of different segmentation approaches for automatic detection of Glaucoma by comparing and measuring the different parameters of fundus images with normal images and abnormal images.*

Key word: ***CDR, Classification, Fundus images, Glaucoma, Optic Disc, Segmentation.***

I.INTRODUCTION

A. Overview Of Glaucoma

Glaucoma is a disease of the main nerve of vision called optic nerve, which is gradually damaged. It affects the peripheral vision and at the end it leads to blindness, if the disease is left untreated [1]. According to World Health Organization (WHO), Glaucoma is the leading source of vision loss; that contributes to 5.2 million cases of blindness and can potentially affect 80 million people in the next decade roughly [2]. In general Glaucoma is caused due to an increased pressure inside the eye called intraocular pressure, the pressure increases due to failure or blockage of the drainage system of the eye. The front chamber of the eye is the tiny space in front portion of the eye. The liquid flow in and out of the chamber and this fluid is called aqueous humor. The pressure inside the eye harms the optic nerve through which retina direct light to the brain where they are recognized as images and makes vision possible.

Glaucoma is a disease that causes damage to the eye's optic nerve and gets poorer over time without any symptoms. In other patients the damage may be due to poor blood supply to the essential optic nerve fibers, a weakness in the structure of the nerve, and a problem in the nerve fibers. The image of the intraocular pressure inside the eye and the damage to the optic nerve is shown in Fig 1. This disease tends to be hereditary and may not show up until later in lifetime. The intraocular pressure can break the optic nerve, which sends the images to the brain.

Received on: 03.05.2020
Accepted on: 01.07.2020
Published on: 16.08.2020

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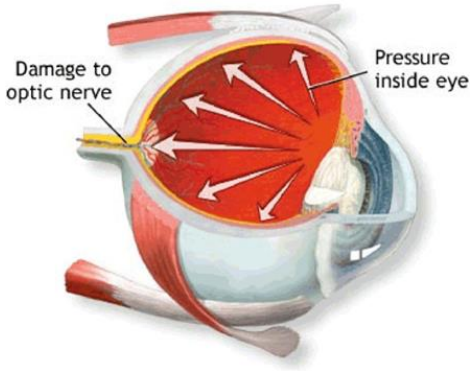

Fig. 1. Image of Eye with Glaucoma

The damage of the optic nerve from eye pressure continues, glaucoma will cause permanent loss of vision. Without treatment, glaucoma can cause total blindness in a few years. So the early detection of this disease is essential to prevent the permanent blindness. In this paper, a broad review on existing segmentation approaches for automatic detection of anatomical features related to glaucoma from fundus images, which provides insights for future directions on automatic detection of glaucoma.

B. Types of Glaucoma

1) Open-Angle Glaucoma- It is the most general form of glaucoma, and it is the reason for 90% of all glaucoma causes. It is caused by the slow blockage of the drainage canals, resulting in increased eye pressure. There is a wide and open angle between the iris and cornea. It rises gradually and the symptoms and damage that are not observed. Open-Angle is the angle where the iris meets up the cornea as broad and open as it should be. The damage to the optic nerve is quite slow and pain-free and a large portion of vision can be lost before the problems are noticed. Open-angle glaucoma is also named as primary or chronic glaucoma.

2) Angle-Closure Glaucoma - It is a less common form of glaucoma. It is due to blocked drainage canals, results a rapid rise in intraocular pressure which begins a painful attack inside the eye. There is a closed or narrow angle between the iris and cornea. It develops quickly, the symptoms and damage that are usually very clear and visible. It demands instantaneous medical attention. The angle-closure is also called acute glaucoma or narrow angle glaucoma. Unlike open-angle glaucoma, the angle- closure glaucoma is a result of the angle between the iris and cornea closing.

3) Normal-tension Glaucoma – It is also called as low-tension glaucoma or normal-pressure glaucoma. In this type of glaucoma, damage is caused to the optic nerve without any eye pressure which exceeds the normal range about 10-20 mmHg (“mmHg” refers to millimeters of mercury, a scale used to record eye pressure). The reason is unknown. People in higher risk for normal tension glaucoma have a family background of this disease normal-tension glaucoma, or they have a background of heart disease, like irregular heart rhythm or beat.

4) Congenital Glaucoma - This type of Glaucoma happens for children when there’s incorrect or incomplete development of the eye’s drainage canals during prenatal period. This is a very rare condition that may be hereditary. It is also called as childhood glaucoma, infantile or pediatric glaucoma. It is detected within the first year of baby life.

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5) *Secondary Glaucoma* - This type of Glaucoma can occur as the result of an eye injury, irritation and swelling, tumor, in advanced cases of cataract or diabetes or by certain drugs like steroids. The impact may be mild or severe. The treatment depends on its type, whether it is open-angle or angle-closure glaucoma.

6) *Pigmentary Glaucoma* - It is a form of secondary open-angle glaucoma, occurs when the pigment granules that are in the back of the iris (the portion which is colored) break into the clear fluid produced inside the eye. These tiny pigment granules flow towards the drainage canals in the eye and slowly block them, causes eye pressure to rise.

7) *Exfoliative Glaucoma* – This type occurs when a flaky, dandruff like material peels off the external layer of the lens inside the eye. The material assembles in the angle between the cornea and iris and it can block the drainage system of the eye, causes eye pressure to rise. It is also called pseudo Exfoliative glaucoma.

8) *Neovascular Glaucoma* - The abnormal formation of new blood vessels on the iris and over the eye's drainage channels can cause this form of open-angle glaucoma. Neovascular glaucoma is connected with other defects, most often diabetes. It certainly not happens on its own. The new blood vessels block the fluid from exiting through the trabecular meshwork (the eye's drainage canals), increases eye pressure.

9) *Uveitic Glaucoma* - It causes irritation, swelling and inflammation in the middle layer of the eye called uvea. The uvea supplies most of the blood to the retina. Increased eye pressure in uveitis can result from the inflammatory process itself or the medication (steroids) used to treat it.

10) *Traumatic Glaucoma* - An injury to the eye may cause traumatic glaucoma. This occur immediately later the injury or by years later. It is due to blunt injuries that hurt the eye (called blunt trauma) or by injuries that penetrate the eye.

C. Clinical Methods For Diagnosing Glaucoma

The tests should be conducted for suspecting Glaucoma or Ocular Hypertension are eye pressure test (Tonometry), examine optic nerve (Ophthalmoscopy), visual field test (Perimetry), angle in the eye where the iris meets the cornea (Gonioscopy) and corneal thickness(Pachymetry).

Tonometry uses a device called a tonometer to measure the inner pressure of the eye. The range for normal pressure is about 12-22 mmHg. Most glaucoma cases are diagnosed with pressure above 21 Hg.

Ophthalmoscopy helps to examine the optic nerve for glaucoma damage. Eye drops are applied to dilate the pupil and then use a small device with a light on the end to light and magnify the optic nerve or by a warm puff of air. The optic nerve that is cupped or not a healthy pink color is cause for concern. The other ophthalmoscopy technologies include: Heidelberg Retina Tomography (HRT), a special laser which produces a three-dimensional high-resolution view of the optic nerve. This test offers clinicians with measurements of nerve fiber damage or loss. The Nerve Fiber Analyzer uses laser light for measuring the thickness of the nerve fiber layer.

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Optical Coherence Tomography (OCT) measures the mirror image of laser light much like an ultrasound measures the reflection of sound, and can directly measure the thickness of the nerve fiber layer and create a three-dimensional representation of the optic nerve.

Perimetry is a visual field test to decide the vision has been affected by glaucoma. During the test, the patient asked to look straight and then indicate when a moving light passes the peripheral vision. This is helpful to draw a map of the vision.

Gonioscopy is a diagnostic exam that helps to determine whether the angle where the iris meets the cornea is open and wide or narrow and closed. During the exam, eye drops are applied to numb the eye and a distinct hand-held contact lens is gently placed on the eye. This contact lens has a mirror and it shows whether the angle between the iris and cornea is closed and blocked or wide and open.

Pachymetry is used to measures the thickness of the cornea—the clear window in the front of the eye. Corneal thickness is likely to influence eye pressure readings. If cornea is thicker than average, pressure readings with a tonometer is higher.

II. SEGMENTATION APPROACHES

Thousands of different segmentation techniques have been developed by different researchers and are present in the literature, but there is not a single method which can be considered good for different images so far, all the methods are not considered good for a particular type of image [3]. Many segmentation methods have been proposed in the literature and the categories are as follows.

A. Threshold method

Threshold operation converts a multilevel image into a binary image i.e., it chooses a proper threshold limit T, to divide image pixels into several regions and separates the objects from background. Any pixel (x, y) is considered as a part of object if its intensity is greater than or equal to the threshold limit i.e., the input image f(x, y) ≥T, else pixel belong to background [4]. The output image g (x, y) is calculated as follows.

$$g(x, y) = \begin{cases} 1, \text{ if } f(x, y) \geq T \\ 0, \text{ if } f(x, y) < T \end{cases} \quad (1)$$

The two types of thresholding methods are global (single) and local (adaptive) thresholding. Based on the selection of thresholding value, it is decided as global or local. When T is constant, then it is called global thresholding otherwise it is called local thresholding. Most commonly used global thresholding methods are entropy based thresholding, Otsu method etc [5]. Some commonly used Local thresholding techniques are simple statistical thresholding, histogram transformation thresholding, 2-D entropy-based thresholding etc [6]. Because of the advantage of simple and easy implementation, the global threshold has been a popular technique in many years [7].

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Major thresholding techniques proposed by different researchers are P-tile method, Mean method, Histogram dependent technique, Edge Maximization technique, and visual technique. The advantages of threshold techniques are: (1) Fast and simple technique, most often used. (2) Easy in hardware, intrinsically parallel. (3) Computationally inexpensive (4) Work in real-time applications. The Limitations of this technique are: (1) Neglects the spatial information of the image. (2) Highly noise sensitive. (3) Selection of threshold value is crucial and often results in over or under segmentation.

B. Region Based Method

Region based segmentation method divides an image into different regions based on pre-defined criteria, i.e., color, intensity, or object. Region based segmentation methods are categorized into three main categories, i.e., region growing, region splitting, and merging [8]. For image segmentation region growing method is a well-developed technique. Based on some predefined criteria this method extracts the image region. An operator manually selects a seed point and extracts all pixels that are connected to the initial seed based on some predefined criteria.

Watershed Transform is a technique that uses the region growing approach and searches for pixel and region similarities for segmentation based on an image gradient. The objective of this algorithm is to find the watershed lines. The advantage of Region based methods are: (1) Provides superior results compared to other segmentation methods. (2) It Provides flexibility to choose between interactive and automatic techniques to segment the given image. (3) Since it flows from inner point to outer region more likely to get clear boundary for the objects. (4) If proper seed is selected it gives very accurate result than any other methods. The limitations of Region based methods are: (1) Formulation of Stopping rule for segmentation is a difficult task. (2) A good segmentation result depends on a set of “correct” choice for the seeds and can direct to erroneous segmentation results if user specifies a noisy seed. (3) The seed selection process in itself requires manual interventions, and is error-prone.

C. Edge Based Detection Method

Edge detection which tries to identify points in a digital image where there is an abrupt change in image brightness or there is a difference in intensities. These points are then connected together to form closed object boundaries. The result of segmentation using edge detection is a binary image [9].

Gray histogram and Gradient are two main methods for edge detection for image segmentation [10]. Several operators are used by edge detection methods are Classical edge detectors, zero crossing, Laplacian of Guassian (LoG) [11], and color edge detectors etc [12]. Edge detection algorithms require a balance between detecting edges accurately and reducing the level of noise. If the level of accuracy is too high, noise will generate detection of numerous additional and fake edges. On the other hand, to reduce the level of noise too greatly [13], it might reduce the accuracy of the edges and many of the useful edges might not be detected. Thus, edge detection algorithms are usually suitable for images that are very simple and noise free [14]. The advantages of Edge Base Detection methods are: (1) Second order operators give reliable results. (2) Useful in calculating the number of different objects present in the given image. The drawbacks by using this method are: (1) No single operator can fit for all variety of images and the computational complexity increases with the size of operator. (2) Many times the edges obtained are not continuous. (3) Noise may result in an erroneous edge.

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D. Methods Based on PDE (Partial Differential Equation)

Image segmentation based on PDEs is commonly carried out by active contour model or snakes. The main idea of snake is transforming a segmentation problem into a PDE framework.

Some well-known methods of PDE used for image segmentation are Snakes, Level-Set, and Mumford shah method. Snakes are computer generated curves that move within the image to find out object boundaries under the influence of internal and external forces. Level set method is used to represent the curves or surfaces as the zero level set of a higher dimensional hyper surface. This technique not only provides more accurate numerical implementations but also handles topological change very easily. The Mumford-Shah model uses the global information of the image as the stopping criterion to segment the image and this method takes advantage of the entire information of the image to result in the best image segmentation [15]. The main advantage of the method is very fastest method and more suitable for time critical application. The limitation of the method is more computational complexity.

E. Clustering Techniques

Clustering is a process of organizing the groups based on its attributes or patterns. The method describes each segment by its texture and boundary shape. It is an unsupervised learning task, where one needs to identify a finite set of categories known as clusters to classify pixels [16]. Without using training data they normally perform as classifiers. To compensate for the lack of training data, this iteratively alternate between segmenting the image and characterizing the properties of each class.

There are three commonly used clustering algorithms; k-means clustering algorithm, fuzzy clustering algorithm, and expectation-maximization algorithm [17]. The k-means clustering algorithm clusters data by iteratively computes a mean intensity for each class and segments the image by classifying each pixel in the class with the neighboring mean. Fuzzy clustering divides the input pixels into clusters or groups on the basis of some similarity criterion, such that similar pixels belong to same cluster.

Fuzzy clustering algorithms include Fuzzy c-means algorithm (FCM), Gustafson-Kessel (GK), Gaussian mixture decomposition (GMD), Fuzzy c-varieties (FCV), Adaptive fuzzy c-varieties algorithm (AFC), Fuzzy c-shells algorithm (FCS), Fuzzy c-spherical shells algorithm (FCSS), Fuzzy c-quadric shells algorithm (FCQS), Fuzzy c-rectangular shells algorithm (FCRS) and etc. The pros of the fuzzy is, it uses partial membership therefore more useful for real problems and the cons of the method is determining membership function is not easy.

F. Pattern Recognition Techniques

Pattern recognition techniques that seek to partition a feature space derived from the image using data with known labels [18]. The pattern recognition process can be viewed as a twofold task, namely, developing decision rules based on human knowledge (learning) and using them for decision making regarding an unknown pattern (classification). The systems are in many cases trained from labeled "training" data (supervised learning), but when no labeled data are available other algorithms can be used to discover previously unknown patterns (unsupervised learning). A simple classifier is the nearest-neighbor classifier, in which each pixel is classified in the same class as the training datum with the closest intensity. The k-nearest-neighbor classifier is a generalization of this approach and it is considered a nonparametric classifier because it makes no underlying assumption about the statistical structure of the data. A normally used parametric classifier is the

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maximum-likelihood or Bayes classifier. Other parametric and nonparametric classifiers are described elsewhere [19]. The advantage of the method is to perform the segmentation and the method is used to model relationships between inputs and outputs. The disadvantages are it is more complicated and it has restrictions on shape parameters.

G. Artificial Neural Network Approach

Artificial neural networks (ANNs) are parallel networks of processing elements or nodes that simulate biological learning. Image is mapped to the neural network and is trained with training sample set in order to determine the connection and weights between nodes. Then the new images are segmented with trained neural network [20]. The Segmentation is performed using pixel classification and edge detection [21]. ANNs can also be used in an unsupervised fashion as a clustering method [22], as well as for deformable models [23]. Because of the many interconnections used in a neural network, spatial information can easily be incorporated into its classification procedures. Although ANNs are inherently parallel, their processing is usually simulated on a standard serial computer, thus reducing this potential computational advantage.

Some of the mostly used neural networks for image segmentation are Hopfield, BPNN, FFNN, PCNN, MLFF, MLP and SOM. The benefit of the ANN technique is no need to write complex programs and the limitation is more wastage of time in training.

III. PREVIOUS WORK RESULTS

The fundus images from various databases of both normal and abnormal fundus images are taken by the authors and applied with the combining of techniques to diagnose glaucoma in fundus image and the result obtained is shown in the table below.

TABLE I
COMPARATIVE ANALYSIS OF PRIOR WORK

METHOD	SAMPLE IMAGES	SUCCESS RATE
PCA, Mathematical Morphology (Sandra et al., 2013) [24].	DRIONS, DIARETDB1, DRIVE, MESSIDOR &ONHSD database images.	94%
P-Tile Method and Canny edge Detection filter (Yuji et al., 2010) [25].	Dataset of 79 images including 25 Glaucoma images.	85%
Statistical Techniques (Cemal et al., 2011) [26].	STARE Dataset images.	97%
Sliding Window and Support Vector Regression model (Y. Xu et al., 2011) [27].	ORIGA Clinical Dataset images of 500 samples.	73.2%
Morphological and edge detection techniques followed by the Circular Hough Transform (Aquino et al., 2010) [28].	Dataset of 1200 images from MESSIDOR database.	99%
Wavelet Based Filter and Neural Network Classifier (Celina et al.,	Dataset of 15 abnormal images out of 30 normal	100%

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2013) [29].	images	
Circular Transformation Technique (S. Lu et al., 2011) [30].	STARE dataset, the ARIA dataset, and the MESSIDOR dataset.	99.75%, 97.5%, & 98.77%
K-Means, Matched filter and Local entropy thresholding Code in C++ using OpenCV (K. Narasimhan et al., 2012) [31].	A batch of 50 retinal images (25 normal set and 25 abnormal set) obtained from the Aravind Eye Hospital	90%
SVM, Naive Bayesian, and Random-Forest Classifiers (Acharya et al., 2011) [32].	Large samples of fundus images	91%
2-D Gaussian Matched Filter (Aliaa Abdel et al., 2008) [33].	STARE project's dataset, containing 81 fundus images of both normal and diseased retinas, and DRIVE dataset of 40 images	98.77% and 100%
PR Approach with a 2-stage classification (Bock et al., 2007) [34].	Data set of 200 real images of healthy and glaucomatous eyes.	86%
Student's t-tests, Anisotropic filtering & Morphological operations (Vermeer et al., 2006) [35].	A collection of different fundus images	93%
Fuzzy min-max neural network (Abirami et al., 2013) [36].	A batch of 39 Anterior Segment-OCT (AS-OCT) images.	97%
Linear Discriminant Analysis, Adaptive Histogram Equalization, Inpainting And Morphological Operations. (R. Preethi et al., 2014) [37].	Diseased samples in 48 cases out of 50 images	96%
Random-Forest Classifier, Z-Score Normalization And Feature-Selection Methods (Priya kumbhare et al., 2014) [38].	Different normal and abnormal images	91%
Hill climbing technique and k means clustering (S.Kavitha et al., 2012) [39].	A large set of different fundus images	97%
ANN. (Sheeba O. et al., 2014) [40].	Dataset of sample images	95%

IV. PROPOSED SYSTEM

This paper proposes the technique of getting the sample retinal fundus images through web and the CDR is calculated using an efficient method and immediately responds the patient whether the condition of eye is normal or it is affected by glaucoma.

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So the patient gets benefited and it is correctly diagnosed from the home itself and then they can take proper medicine or undergo surgery in a well-timed manner to avoid total blindness.

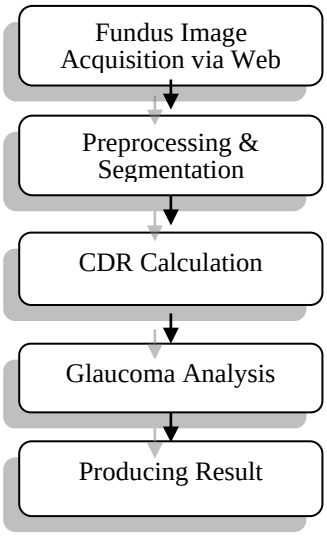

Fig. 2. Proposed System Block diagram

V. CONCLUSION

From the review of the papers it has been observed that many researchers and experts implemented different segmentation techniques to locate the optic disc for the diagnosis of Glaucoma and shown better results. Glaucoma is the second major cause of blindness in the world. Hence its detection and diagnosis are very essential. Lot of recent research is being carried for detection of Glaucoma using fundus images, but still detection of progression of Glaucoma in patient remains to be researched. In future, there is a need to develop more accurate automated techniques for glaucoma detection.

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