A Survey on Image Processing Techniques for Glaucoma Detection

Dr. PSJ Kumar [1], Ms. Sukanya Banerjee [2]

[1] *Professor and Head, Department of Computer science and Engineering, JISCE, Kalyani, India*

[2] *PG Scholar, Department of Computer science and engineering, JISCE, Kalyani, India*

ABSTRACT:

Automatic analysis of retina images is becoming an important screening tool now days. This technique helps to detect various kind of risks and diseases of eyes. One of the most common diseases which cause blindness is Glaucoma. This disease happens due to the increase of Intraocular Pressure (IOP). Early detection of this disease is essential to prevent the permanent blindness. Screenings of glaucoma based on digital images of the retina have been performed in the past few years. Several techniques are there to detect the abnormality of retina due to glaucoma. The key image processing techniques are image registration, image fusion, image segmentation, feature extraction, image enhancement, morphology, pattern matching, image classification, analysis and statistical measurements. The main idea behind this paper is to describe a system which is mainly based on image processing and classification techniques for detection of glaucoma by comparing and measuring different parameters of fundus images of glaucoma patients and normal patients.

Keywords: Glaucoma, K-Means Clustering, Thresholding, Fundus Image, CDR, ISNT, K-Nearest Neighbor, Support Vector Machine, Bayesian

[1] INTRODUCTION

Glaucoma is a disease of the optic nerve involving loss of retinal ganglion cells in a characteristic pattern of optic neuropathy. Our eye has pressure just like our blood which is called intraocular pressure. When this intraocular pressure (IOP) increases to a certain level, it damages the optical nerve. This can result in decreased peripheral vision and eventually blindness. Manual analysis of eye images is fairly time consuming and the accuracy of parameters measurements varies between experts. Hence, there arises the need for an automated technique. Automatic analysis of retina images is becoming an important screening tool now days. This technique helps to detect various kind of risks and diseases of eyes. There are mainly two types of glaucoma one is open angle or chronic glaucoma and another one is closed angle or acute glaucoma, both are responsible for increasing the intraocular pressure. In early stage of glaucoma, Patients do not usually have any visual signs or symptoms. As the disease progress it causes of losing the vision and the patients may suffer from tunnel vision (being only able to see centrally). Therefore early detection of this disease is essential to prevent the permanent blindness. There are several automated glaucoma detection techniques already available. In this study, we are trying to do a review of all those available techniques. Each of the techniques has some advantages as well as disadvantages. Based on this study, we can determine which technique can be applied in which scenario to obtain the optimal result.

[2] REVIEW OF AUTOMATED GLAUCOMA DETECTION TECHNIQUES

Neelapala Anil Kumar et al. [1] had devised a technique for automated detection of glaucoma in eye by using angel open distance 500 calculations. This technique is a 3 step methodology. In the 1st step, three features of the ultrasound images i.e. contrast, resolution and clarity is significantly improved for effective anterior chamber segmentation. In 2nd step, classification of several regions of ultra sound image is done to eliminate the unwanted image.

Then they crop the anterior chamber region and the reference axis is located. Finally, step 3 focuses on several steps involved in exact determination of the anterior chamber angle for finding out whether the eye is affected by glaucoma or not. This algorithm is able to correctly diagnose glaucoma in 97% of the cases.

K. Narasimhan et al. [2] devised a new methodology for the detection of glaucoma based on two vital features CDR and ISNT ratio. K-means clustering is recursively applied to ROI to localize the optic disc and optic cup region. An elliptical fitting technique is used to calculate the CDR values. The blood vessels inside the optic disc are extracted by local entropy thresholding and four different masks are used to determine the ISNT ratio. CDR and ISNT ratio are calculated. Then they carried out a performance of the proposed algorithm on three different classifiers. Experiments suggest that the maximum classification rate of 95% for glaucoma can be achieved when using the SVM classifier.

Preeti Kailas Suryawanshi [3] adopted a technique which extracted ROI from retinal images. Optic disc segmentation is performed on the extracted ROI in order to detect the disc boundary using optimal color channel. The disc boundary obtained from the above step may not denote the exact shape of the disc as boundary can be affected by a large number of blood vessels at the entrance of the disc. Hence, optic disc boundary smoothing is performed using ellipse fitting for capturing near perfect shape of the disc. Optic cup segmentation is also performed. After the cup boundary has been detected, ellipse fitting is again employed to eliminate some of the cup boundary's sudden changes in curvature. Ellipse fitting becomes especially useful when portions of the blood vessels in the neuro-retinal rim are included within the detected boundary. The CDR is consequentially obtained based on the height of detected cup and disc. If the cup to disc ratio exceeds 0.3 then it indicates the abnormal condition that is the presence of glaucoma.

Pachiyappan et al. [4] proposed a technique for Glaucoma diagnosis utilizing fundus images of the eye and the optical coherence tomography (OCT). The Retinal Nerve Fiber Layer (RNFL) can be broadly classified into anterior boundary (top layer of RNFL), the posterior boundaries (bottom layer of RNFL) and also the distance in between the two boundaries. Glaucomatous and Non-Glaucomatous classification was done based on the thickness of the nerve fiber layer which is nearly 105 µm. This approach provided optical disk detection with 97.75% accuracy.

Anusorn et al. [5] presented a method to calculate the CDR automatically from fundus images. The image pre-processing is the first step to localize the optic disc and cup. The optic disc is extracted using an edge detection approach and a variation level-set approach separately. The optic cup is then segmented using a color component analysis method and threshold level-set method. After obtaining the contours, an ellipse fitting step is introduced to sharpen the obtained results. Using 44 images, the performance of this approach is evaluated using the proximity of the calculated CDR to the manually graded CDR. The results indicating that our approach provides 89% accuracy in glaucoma analysis.

Kumar et al. [6] proposed an algorithm for glaucoma detection. In this algorithm, segmentation and feature extraction of an image is done using active contours. Next, the initial point of interested feature is determined accordingly. Then masking is done by cropping the region of interest. Finally, calculation of the open angle of the anterior chamber is conducted. If the open angle is found to be greater than threshold angle, the eye is diagnosed as normal eye. Otherwise, it is diagnosed to be diseased eye.

Aquino et al. [7] presented a new Optic disc (OD) detection technique which is a vital step for automated diagnosis of Glaucoma. In this paper they developed a new template-based approach for differentiating the OD from digital retinal images. This approach uses morphological, edge detection techniques followed by the Circular Hough Transform which helps to get a circular OD boundary approximation. A pixel located within the OD is taken as initial information. Glaucoma is identified by recognizing the changes in depth, shape and

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color that it produces in the OD. Thus, this technique used segmentation as well as analysis to detect Glaucoma automatically.

Chandrika et al. [8] adopted a technique for automated Glaucoma diagnosis. In this technique, optic disk identification is performed on retinal images. Next, thresholding is done to find out the threshold value. After that image segmentation is performed using k-means clustering and Gabor wavelet transform. Then optic disc and cup boundary smoothing is performed using different morphological features. From this CDR can be calculated. If the CDR ratio exceeds 0.3 it indicates high Glaucoma for the tested patient.

Abirami et al. [9] devised a novel automated Glaucoma detection system. The proposed system deals with the Image obtained from Stratus Anterior Segment Optical Coherence Tomography (AS-OCT). The stratus Anterior Optical Coherence Tomography (AS-OCT) images with these diseases are detected and classified from the normal images using the proposed fuzzy min-max neural network based on Data-Core (DCFMN). Data-core fuzzy min-max neural network (DCFMN) depicts strong robustness as well as high accuracy in classification. DCFMN contains two classes of neurons: classifying neurons (CNs) and overlapping neurons (OLNs). CNs is used to classify the patterns of data. The OLN can handle all kinds of overlap in different hyper boxes. A new type of membership function considering the characteristics of data and the influence of noise is designed for CNs in the DCFMN. The membership function of Overlapping Neurons (OLNs) deals with the relative position of data in the hyper boxes. This algorithm is performed on a batch of 39 anterior segment- Optical Coherence Tomography (AS-OCT) images. The performance of the proposed system is excellent and a classification rate of 97% is achieved.

Naz et al. [10] proposed a system where the main feature which is been considered here for identifying the vision impaired disease glaucoma is the cup-to-disk ratio (CDR), which specifies the change in the cup area. Increase intra ocular pressure (IOP) results in increase in the area of the cup and this result in dramatic visual loss. In this paper increase in cup area is analyzed by examining the CDR value. The CDR was calculated by taking the ratio between the area of optic cup and disc.CDR > 0.3 indicates glaucoma and CDR ≤ 0.3, is considered as normal image. We examine the mean square error (MSE), pixel signal to noise ratio (PSNR) and signal to noise ratio (SNR) to quantify the performance of the above pre-processing algorithms. The algorithm for the earlier identification of Glaucoma by estimating CDR was developed in this paper. The optic disc was segmented using the three methods namely edge detection method, optimal thresholding method and manual threshold analysis are proposed in the paper. For the cup, threshold level-set method is evaluated. The performance of various methods was evaluated by comparing the CDR. It was found that the manual threshold method and edge detection method provides better estimation of CDR. The method has been applied to nearly forty images and the CDR was correctly identified.

Mary et al. [11] devised a technique for glaucoma detection where optic disc segmentation via pyramidal decomposition is carried out on the retinal images which gives a better performance than other algorithms. It is important to note that although Pyramidal decomposition method with the help of Hough transform is guaranteed to converge though it is very sensitive to noise. So, multiple initializations are being used to yield a better performance. Finally, they have proposed a model approach using discriminant analysis which has shown an improvement over the rest.

Pruthi et al. [12] developed an automated glaucoma detection system having six different stages. The system is comprised of six different stages: Preprocessing, Region of Interest (ROI) Extraction, Feature Extraction stage, Calculation of CDR, Classification and Performance analysis stage. The system takes as input a fundus image. In the preprocessing stage, illumination correction and blood vessel removal takes place. After the analysis of entire image, a small square having 360 X 360 pixels is taken around the brightest region is denoted as ROI. Feature extraction is done from the images. In this method the features are extracted from optic disc and optic cup. The diameter of cup and optic disc is used for calculating Cup to disc ratio. It is extracted from the segmented optic disc and cup. The classifiers namely SVM, Back Propagation Neural Network, ANFIS are used to differentiate between normal and abnormal cases of glaucoma. ANFIS, SVM and Back Propagation had achieved accuracy of 97.77%, 98.12% and 97.35% respectively.

L´aszl´o G. Ny´ul [13] devised a novel automated glaucoma classification technique, depending on image features from fundus photographs. In this study, data-driven technique does not need any manual assistance. The system does not depend on explicit structure segmentation and measurements. First of all size differences, non uniform illumination and blood vessels are eliminated from the images. They then extracted the high dimensional feature vectors. Finally compression is done using PCA and the combination before classification with SVMs takes place. The Glaucoma Risk Index (GRI) produced by the proposed system with a 2-stage SVM classification scheme achieved 86% success rate. This is comparable to the performance of medical experts in detecting glaucomatous eyes from such images. Since GRI is computed automatically from fundus images acquired by an inexpensive and widely available camera it is suggested that the system could be used in glaucoma mass screenings.

Archana et al. [14] developed a novel approach for glaucoma detection. The main motive of this study is to map the person's eye color image with database of images consisting of normal person as well as glaucoma affected person. The different color variations inside the eye can be compared by using images taken from high definition laser camera. They are also known as fundus images. The feature extraction of these fundus images may be carried out using MATLAB software tool. By measuring the color pixels in the affected area the observation shows that the person is suffering from Glaucoma or not. To detect if a person is suffering from Glaucoma or not, a test is conducted using the image of a normal person which is kept as reference and then several comparison are carried out with the clinical observations of the person's image. Further if the result is positive (person is affected with Glaucoma) then also check for the three types of Glaucoma i.e. Primary Angle Closure Glaucoma, Secondary Glaucoma, and Congenital Glaucoma.

Hatanaka et al. [15] proposed a technique for detection of glaucoma utilizing a vertical cup-to-disc ratio. Finding the cup area is very difficult task as the proposed method tries to measure the cup-to-disc ratio using a vertical profile on the optic disc. After that the blood vessels of the disc were removed from the image. Then canny edge detection filter was used for detection of the edge of optic disc. The edge of the cup area on the vertical profile was calculated by the threshold technique. Finally, the vertical cup-to-disc ratio was found out. In this study, they also presented a method for recognizing glaucoma by calculating C/D ratio. The method correctly identified 80% of glaucoma cases and 85% of normal cases.

Liu et al. [16] designed automated glaucoma detection technique through medical imaging informatics (AGLAIA-MII) that takes into consideration everything starting from patient personal data, patient's genome information for screening and medical retinal fundus image. The AGLAIA-MII architecture uses information from multiple sources, including subjects' personal data, imaging information from retinal fundus image, and patients' genome information. Features from each data source will be extracted automatically. Subsequently, these features will be passed to a multiple kernel learning (MKL) framework to generate a final diagnosis outcome. AGLAIA-MII achieved an area under curve value of 0.866, which is much better than 0.551, 0.722 and 0.810 obtained from the individual personal data, image and genome information components, respectively. This methodology had shown a substantial improvement over the previous glaucoma detection techniques depending on intraocular pressure.

Huang et al. [17] developed an automated classifier based on adaptive neuro-fuzzy inference system (ANFIS) which differentiate between normal and affected eyes. Stratus optical coherence tomography (OCT) technique was used for calculation of glaucoma variables (optic nerve head topography, retinal nerve fiber layer thickness). Decision making

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was performed in two stages: feature extraction using the orthogonal array and the selected variables were treated as the feeder to adaptive neuro-fuzzy inference system (ANFIS), which was trained with the back-propagation gradient descent method in combination with the least squares method. With the Stratus OCT parameters used as input, receiver operative characteristic (ROC) curves were generated by ANFIS to classify eyes as either glaucomatous or normal. The mean deviation was -0.67 ± 0.62 dB in the normal group and -5.87 ± 6.48 dB in the glaucoma group. The inferior quadrant thickness parameter was used for distinguishing between normal and glaucomatous eyes.

Vermeer et al. [18] presented a model for detecting the change in images. These images were collected by scanning laser polarimetry, for tracking the glaucomatous progression. This methodology depends on image set of 23 healthy eyes and includes colored noise, incomplete cornea and masking is done by the retinal blood vessels. There are two more methodologies for tracking progression by taking up one or two follow-up visits into the account. Then they are tested on these simulated images. Both of these methods are depending on Student's t-tests, anisotropic filtering and morphological operations. The images simulated by this technique are visually pleasing and also show statistical properties to the real images. This results in optimizing the detection methods. The results reveal that tracking the progression depending on two follow-up visits marks a great improvement in sensitivity without affecting the specificity adversely.

Cheng et al. [19] proposed a new technique for glaucoma detection based on RetCam. In this study, for glaucoma detection RetCam is used which is an imaging modality that captures the image of irridocorneal angle. The manual grading and analysis of the RetCam image is quite a time consuming process. In this study, they developed an intelligent system for analysis of iridocorneal angle images, which can distinguish between open angle glaucoma and closed angle glaucoma automatically.

Joshi et al. [20] developed an automated OD parameterization technique depending on segmented OD and cup regions which are collected from monocular retinal images. An OD segmentation technique is developed which works by integrating the information of local images around each point of interest in multidimensional feature space. This technique is quite robust against any form of variations found in the OD region. They utilized a cup segmentation technique depending on anatomical information such as vessel bends at the cup boundary, which is quite vital as considered by glaucoma experts. The bends in a vessel can be easily detected by utilizing a region of support concept, which helps in selecting the right scale for analysis. In this study, a multi-stage strategy is used to find a reliable subset of vessel bends called r-bends, which is followed by a local spline fitting in order to find the desired cup boundary.

Acharya et al. [21] developed an automated glaucoma detection system by combining the texture and higher order spectra (HOS) features obtained from fundus images. Naive Bayesian, Support vector machine, random-forest classifiers and sequential minimal optimization are used to perform supervised classification. After z-score normalization and feature selection, the results reveal that the texture and HOS based features. When these features are combined with a random-forest classifier it performs much better than the other classifiers. This method correctly diagnoses the glaucoma images with 91% accuracy.

Grau et al. [22] developed a new segmentation algorithm, depending on the expectation-maximization. This algorithm used an anisotropic Markov random field (MRF). In this study, structure tensor had been used to characterize the predominant structure direction as well as spatial coherence at each point. This algorithm had been tested on an artificial validation dataset that is similar to ONH datasets. It has shown significant improvement over an isotropic MRF. This algorithm provides an accurate, spatially consistent segmentation of this structure.

Kavitha et al. [23] adopted super-pixel classification based disc and cup segmentation technique for glaucoma screening. This paper is presented and evaluated for Glaucoma detection in patients using multimodalities including CSS, Contrast Enhanced Histograms, K-Means clustering, SLIC and Gabor wavelet transformation of the color fundus camera image to obtain accurate boundary delineation. Using structural features like CDR (Cut to Disc Ratio), eccentricity and compactness the ratio value exceeds 0.6 shall be recommended for further analysis of a patient to the ophthalmologist.

Inoue et al. [24] developed a glaucoma screening technique using super pixel classification on optic disc and optic cup segmentation. In optic disc segmentation, histograms were utilized to classify each super pixel as disc or non-disc. The quality of the automated optic disc segmentation is calculated using a self-assessment reliability score. For optic cup segmentation, along with the histograms, the location information is also included to boost up the performance. In this proposed segmentation approach a database of 650 images was used with optic disc and optic cup boundaries which had been manually marked by professionals. The results showed an overlapping error of 9.5% and 24.1% in disc and cup segmentation, respectively. Lastly the cup to disc ratio for glaucoma screening was computed.

Bock et al. [25] developed an automated glaucoma classification system that does not at all depend on the segmentation measurements. They had taken a purely data-driven approach which is very useful in large-scale screening. This algorithm undertakes a standard pattern recognition approach with a 2-stage classification step. In this study, various image-based features were analyzed and integrated to capture glaucomatous structures. There are certain disease independent variations such as size differences, illumination in homogeneities and vessel structures which are removed in the preprocessing phase. This system got 86% success rate on a data set of 200 real images of healthy and glaucomatous eyes.

[3] CONCLUSION

In this review paper, we have studied many works related to automated glaucoma detection. Glaucoma is one of the vital factors contributing to majority of blindness worldwide. So, we need to develop some inexpensive automated technique for accurate detection of different stages of glaucoma. These techniques will be of great help in less developed countries where there is an acute shortage of ophthalmologists. There have been several works done earlier in this field. In future, we need to develop more accurate, robust as well as affordable automated techniques for glaucoma detection so that the benefits are passed on the poorest of poor people. Once glaucoma is correctly diagnosed then they can take proper medicine or undergo surgery in a timely manner to avoid total blindness.

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