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Research Article

GLAUCOMA DETECTION - A SURVEY

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ABSTRACT

Medical image processing is a technique and process of creating visual representation of the interior of a body. The fast growing development of digital imaging and computer vision has increased the potential of using the image processing technologies in medicine. And Image processing is particularly useful in medical diagnostic systems. The image of the retina is used to provide the necessary information regarding the sensory part of the visual system. Some of the retinal diseases are Pink Eye, Styes and Chalazia, Dry Eye, Flashes and Floaters, Diabetic Eye Disease, Glaucoma, Macular Degeneration. These retinal diseases are lead to the blindness. Among these Disease Glaucoma is one of the leading causes of blindness. Glaucoma is a condition that causes damage to eye's optic nerve. It is one of the leading causes of blindness. It can happen at any age, but is more common in older adults. The optic nerve, which transmits images to the brain, was affected by the increased pressure, called intraocular pressure. If this continues, Glaucoma can lead to permanent vision loss. Without treatment, Glaucoma can cause permanent blindness within a few years. Early detection, through regular and complete eye exams, is the key to protecting our vision from damage caused by glaucoma. This survey paper present a image processing technique for Automated diagnosis of Glaucoma.

INTRODUCTION

Glaucoma is the leading cause of irreversible blindness in the world, affecting more than 80 million people. However, because the disease remains largely asymptomatic as it progresses, researchers estimate that more than 50 percent of individuals are unaware that they are afflicted until it's too late. Glaucoma is a condition that causes damage to our eye's optic nerve and gets worse over time. It is one of the leading causes of blindness .It can occur at any age but is more common in older adults. The increased pressure, called intraocular pressure, can damage the optic nerve, which transmits images to your brain. If the damage continues, Glaucoma can lead to permanent vision loss. Without treatment, Glaucoma can cause total permanent blindness within a few years. Early detection, through regular and complete eye exams, is the key to protecting our vision from damage caused by glaucoma. A complete eye exam includes five common tests to detect glaucoma.They are Tonometry, Ophthalmoscopy, Perimetry, Gonioscopy, Pachymetry. Among these five Tonometry is one of the famous method to measure the pressure in our eye. During tonometry, eye drops are used to numb the eye. Then a doctor or technician uses a device called a tonometer to measure the inner pressure of the eye. A small amount of pressure is applied to the eye by a tiny device or by a warm puff of air. But these Tonometry test requires both involvement from the doctor, a specialized and expensive pressure sensitivity machine, and the availability of a properly trained operator and Tonometry machine that conducts the Tonometry test is both expensive and bulky meaning that it is inoperable in areas that cannot support the infrastructure necessary to utilize. The rest of the paper is organised as follows: Image processing technique of automated Glaucoma detection is described in Section II. The Analysis of Glaucoma detection Techniques is described in Section III, with subsections for feature processing and classification. Section IV provide summary of the analysis of Glaucoma detection and the paper ends with conclusion in section V.

Image Processing Technique of Automated Glaucoma Detection

Glaucoma is a disease portrayed by degeneration of optic nerves. So the fall in circulatory system to the optic nerve accommodate the visual field surrenders related with glaucoma. Damage to optic nerve fibre is detected using the

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morphological features of fundus images. Glaucoma can be detected using the following feature,

1. Cup to Disc Ratio (CDR)
2. The ratio of area of blood vessels in inferior-superior side to the nasal-temporal side.
3. Ratio of distance between the optic disc center and optic nerve head to diameter of the optic disc.

Image Pre-processing

Preprocessing is the step taken before the major image processing task. Pre-processing is a common name for operations with images at the lowest level of abstraction -- both input and output are intensity images The aim of pre-processing is an improvement of the image data that suppresses unwanted distortions or enhances some image features important for further processing. Retinal images are acquired with a digital fundus camera which captures the illumination reflected from the retinal surface. Despite controlled conditions, many retinal images suffer from nonuniform illumination given by several factors: the curved surface of the retina, pupil dilation, or presence of diseases among others. The curved retinal surface and the geometrical configuration of the light source and camera lead to a poorly illuminated peripheral part of the retina with respect to the central part. Preprocessing can dramatically improve the performance of image.

Optic Cup Segmentation

Glaucoma is an ocular disorder caused due to increased fluid pressure in the optic nerve. The increased intraocular pressure in glaucoma increases the cup size. Therefore, changes in the cup size and CDR are considered important indications of glaucoma. For optic cup segmentation, thresholding and binarization can be used. Using this method, the given image will convert to the threshold or binarized image. From such binarized image can easily extract optic cup boundary.

Optic Disc Segmentation

Optic disc extraction or segmentation is performed using segmented reference images called "ground truth" on which the optic disc is accurately marked by ophthalmologists. The OD processing includes two main steps: localization (detecting the center point of OD) and segmentation (detecting the disc boundary). The OD segmentation steps start by converting the image to a grayscale image and then implementing the image preprocessing. The blood vessels are removed in the next step to facilitate the segmentation process. The next step in OD segmentation is detecting a circle which matched the location of OD by performing a Hough transform. Subsequent to this, an active contour model is used to obtain the OD boundaries that are as close to the original OD boundaries as possible. Further work can be done to segment the cup disc in order to classify the images into normal and glaucomatous.

Blood vessels segmentation

The blood vessel segmentation in turn helps to provide a method for the detection of Glaucoma .The retinal blood vessels are usually referred to; arteries and veins. Then artery and central vein normally appear near each other in the nasal side of the optical disc center. Blood vessels are clearer in the green component. Information about the structure of the blood vessels can help to classify the severity of the disease and may also serve as a reference during operation. And two strategies have been used for the detection of blood vessels in image. One is the detection of edges; and the other is monitoring that requires a priori knowledge of the position from the image. Information about blood vessels can be used in grading disease severity or as part of process of automated diagnosis of diseases with ocular manifestations. Here the glaucoma is detected by means of ISNT (Inferior, Superior, Nasal, Temporal) ratio.

Feature Extraction

Feature Extraction is the process by which feature of interest within an image are detected and represented for further processing. It is a critical step in most computer vision and image processing solutions because it marks the transision from to non-pictorial data representation. The resulting representation can be subsequently used to a number of pattern recognition and classification techniques.

Cup-to-Disc Ratio (CDR)

The ratio of the size of the optic cup to the optic disc, also known as the cup-to-disc ratio (CDR), the value of CDR which is more than 0.3 is used to assess a patient as a possible glaucoma case.

Classification

The classifiers were chosen based upon their effectiveness in capturing the discriminative properties of these features, the impact of the ranking of features and efficiency, and the efficacy of the classification results. The classifier used to accurately classify normal and Glaucoma Images.

Analysis of Glaucoma Detection Techniques

Shishir Maheshwari, Ram Bilas Pachori U. Rajendra Acharya developed a novel method for Automated Diagnosis of Glaucoma Using Empirical Wavelet Transform and Correntropy Features Extracted from Fundus Images (Shishir Maheshwari *et al*, 2016). work Empirical Wavelet Transform (EWT) is used for automatic detection of Glaucoma. The EWT is used to decompose the image and then correntropy features are obtained from the decomposed EWT components. The extracted features from EWT components are ranked based on t-value feature selection algorithm.Then, these features are used for the classification of retinal images into normal and glaucoma images using Least Squares Support Vector Machine (LS-SVM) classifier.

U.Rajendra Acharya, Sumeet Dua, Xian Du, Vinitha Sree S, and Chua Kuang Chua developed a novel method for glaucoma detection using a combination of texture and Higher Order Spectra (HOS) features from digital fundus images (U.Rajendra Acharya *et al*, 2016). Image contrast improvement using histogram equalization and radon transform was performed for HOS feature extraction. Two types of features extraction: 1) HOS parameters and 2) texture descriptors. HOS elicits both amplitude and phase information of a given signal. HOS consist of moment and cumulant spectra and can be used for both deterministic signals and random processes. And texture descriptors provide measures of properties, such as smoothness, coarseness, and regularity, which indicate a mutual relationship among intensity values of neighboring pixels repeated over an area larger than the size of the relationship Histogram equalization increases the dynamic range of the histogram of an image and assigns the intensity values of pixels in the input image such that the output image contains a uniform distribution of intensities. As a result, the contrast of the image is increased. Then feature selection used to rank the feature in order to select the correct feature and z-score normalization used to normalize the selected feature. Random forest classifier is used to classify the normal and Glaucoma images .Random forest classifier obtained the highest classification accuracy of 91.7% for *z*-score normalized data.

Jun Cheng, Jiang Liu, Yanwu Xu, Fengshou Yin, Damon Wing Kee Wong, Ngan-Meng Tan, Dacheng Tao,Ching-Yu Cheng, Tin Aung, and Tien Yin Wong developed a new method for Optic disc and optic cup segmentation using superpixel classification for glaucoma screening (Jun Cheng *et al*, 2013). In optic disc segmentation, histograms, and center surround statistics are used to classify each superpixel as disc or non-disc. A self-assessment reliability score is computed to evaluate the quality of the automated optic disc segmentation. The disc segmentation comprises: a superpixel generation step to divide the image into superpixel; a feature extraction step to compute features from each superpixel; a classification step to determine each superpixel as a disc or non-disc superpixel to estimate the boundary; a deformation step using deformable models to fine tune the disc boundary.For optic cup segmentation, in addition to the histograms and center surround statistics, the location information is also included into the feature space to boost the performance. In cup segmentation thresholding is used to determine the cup in relying on intensity difference between cup and neuroretinal rim.A support vector machine is used as the classifier. This classifier used to classify disc and non-disc region and also detecting the cup boundary from 2-D fundus images. After obtaining the disc and cup, various features can be computed. Then to compute the CDR. The computed CDR is used for glaucoma screening. When CDR is greater than a threshold, it is glaucomatous, otherwise, healthy.

Madhusudhanan Balasubramanian,, Stanislav Zabic, Christopher Bowd, Hilary W. Thompson, Peter Wolenski, S. Sitharama Iyengar, Bijaya B. Karki, and Linda M. Zangwill developed a new framework for detecting glaucomatous changes in the ONH of an eye using the method of proper orthogonal decomposition (POD) (Madhusudhanan Balasubramanian *et al*, 2009). A baseline topograph subspace was constructed for each eye to describe the structure of the ONH of the eye at a reference/baseline condition using POD. Any glaucomatous changes in the ONH of the eye present during a follow-up exam were estimated by comparing the follow-up ONH topography with its baseline topograph subspace representation Image correspondence measures of $L1$ -norm and $L2$ -norm, correlation, an image Euclidean distance (IMED) were used to quantify the ONH changes.The statistic image mapping SIM of the retina method is based on suprathreshold cluster tests. Wherein the locations with statistically significant changes are chosen using a primary threshold (for example, the locations with $p < 0.05$). Because glaucomatous structural changes affect a contiguous region in the ONH, the locations with significant changes are further grouped into clusters, and the significance of the topograph-level progression is defined based on the significance of the size of the largest cluster of significantly changed locations using a nonparametric permutation test. The Heidelberg retina topograph (HRT) Topographic change analysis method utilizes a mixed-effect three-way an Analysis of variance model to detect superpixel-level changes in the ONH topography. The proposed POD framework captures the instrument measurement variability and inherent structure variability and shows promise for improving the ability to detect glaucomatous change over time in glaucoma management.

M. R. K. Mookiah, U. R. Acharya, C. M. Lim, A. Petznick, and J. S.Suri,*et al*., developed a new method for the automated identification of normal and glaucoma classes using Higher Order Spectra (HOS) and Discrete Wavelet Transform (DWT) features (M. R. K. Mookiah *et al*, 2013). The extracted features are fed to the Support Vector Machine (SVM) classifier with linear, polynomial order 1, 2, 3 and Radial Basis Function (RBF) to select the best kernel function for automated decision making. HOS consist of moment and cumulant spectra. It can be used for both deterministic signals and random. Higher order spectra invariants have been used for shape recognition and to identify different kinds of eye disease. HOS is a non-linear method helps to capture the subtle changes in pixels of the image, which can be used as features for the automated classification. A given signal is decomposed using DWT into approximation and detail coefficients at first level. The approximation coefficients are further decomposed to obtain the next level approximation and detail coefficients to provide DWT representation at a higher level of decomposition. In the first step HOS and DWT features extracted from the digital fundus images. Support Vector Machine (SVM) is a supervised learning methods used for classification and regression. Extracted feature are used for classification of normal and Glaucoma images The higher values of HOS features and lower values of wavelet energy features suggest that glaucoma has a more coarse textural variation than normal.

Sumeet Dua, Yanwu Xu,P. Chowriappa, and S. V. Sree developed a novel technique to extract energy signatures obtained using 2-D discrete wavelet transform, and subjects these signatures to different feature ranking and feature selection strategies (Sumeet Dua *et al*, 2012). And have gauged the effectiveness of the resultant ranked and selected subsets of features using a support vector machine, sequential minimal optimization, random forest, and naive Bayes classification strategies. Discrete wavelet transform used to decomposed the signal then using a fourth-order symlets wavelet is used to extract features and analyze discontinuities and abrupt changes contained in signals. DWT is a multiscale analysis method, in which analysis can be performed on various scales. *z*-score normalization used to normalize the feature then using filter-based approaches to rank the features based on their discriminatory sample. And feature selection schemes to determine the best combination of features to maximize interclass similarity and aid in the convergence of classifiers, such as the support vector machine (SVM), sequential minimal optimization (SMO), random forest, and naive Bayes techniques. These classification techniques accurately classify the normal and Glaucoma images.

R. Bock, J. Meier, L. G. Ny´ul, J. Hornegger, and G. Michelson developed a novel automated glaucoma detection system that operates on inexpensive to acquire and widely used digital color fundus images (R. Bock *et al*, 2010). After a glaucoma specific preprocessing, different generic feature types are compressed by an appearance-based dimension reduction technique. The appearance-based approach analyzes the entire input image data to capture the glaucoma characteristics. To emphasize these desired characteristics in the input data, the variations not related to the glaucoma disease are excluded from the images in a preprocessing step. This includes variations due to image acquisition, such as inhomogeneous illumination or different optic nerve head locations, but also retinal structures not directly related to glaucoma. These feature types are then compressed separately by PCA to gain a low-dimensional image representation for classification. Subsequently, a probabilistic two-stage classification scheme combines these features types to extract the novel Glaucoma Risk Index (GRI) that shows a reasonable glaucoma detection performance. In classification a glaucoma probability and the associated class label such as ‘‘glaucoma” or ‘‘not glaucoma” is computed from the three different feature types that will be denoted as the Glaucoma Risk Index (GRI).SVM classifer used that feature to classify normal and Glaucoma images.

U. R. Acharya, E. Ng, L. W. J. Eugene, K. P. Noronha, L. C. Min, K. P. Nayak, and S. V. Bhandary developed a novel automated glaucoma diagnosis method using various features extracted from Gabor transform applied on digital fundus images (U. R. Acharya *et al*, 2015). In this work used 510 images were to classify into normal and glaucoma classes. Gabor kernels are used to perform the convolution process to obtain coefficients with different frequencies and orientations information. Various features namely mean, variance, skewness, kurtosis, energy, and Shannon, Renyi, and Kapoor entropies are extracted from the Gabor transform coefficients. These extracted features are subjected to principal component analysis (PCA) to reduce the dimensionality of the features. Then these features are ranked using various ranking methods namely: Bhattacharyya space algorithm, t-test, Wilcoxon test, Receiver Operating Curve (ROC), and entropy. Feature ranking and selection is a critical step to select a subset of significant features from the entire set of features. Select the minimum features to get the best classification accuracy. The t-test method compares the population means of the two groups to identify the correlation among the features . Chernoff bound provides exponential decay on tail distributions using independent variables. Hence it is used with Bhattacharyya distance for feature ranking . The ROC based feature ranking selects the features using area between ROC and the random classifier slope. Wilcoxon method is a non-parametric test, which does not assume normal distribution. The basic idea of entropy method is to filter out those features whose expression distributions are relatively random. The features with smaller entropy are more discriminatory. SVM and Naive Bayesian (NB) classifiers to select the best classifier for the automated diagnosis of glaucoma.

J. Nayak, U. R. Acharya, P. S. Bhat, N. Shetty, and T. C. Lim developed a novel method for glaucoma detection using digital fundus images (J. Nayak *et al*, 2009). Image processing techniques, such as preprocessing, morphological operations were performed frequently on the images for the automatic detection of optic disc, blood vessels and computation of the features. Extracted features such as cup to disc (c/d) ratio, ratio of the distance between optic disc center and optic nerve head to diameter of the optic disc, and the ratio of blood vessels area in inferior-superior side to area of blood vessel in the nasal-temporal side. These features are validated by classifying the normal and glaucoma images using neural network classifier.An Artificial Neural Network (ANN) is an information processing unit that is inspired by the way biological nervous systems processes information. It is composed of a large number of highly interconnected neurons working together to solve specific tasks. Data enters at the inputs and passes through the layer of hidden layers, where the actual information is processed and the result is available at the output layer. Usually feed forward architecture is used, where there is no feedback between the layers. The supervised learning algorithm was used for training the neural network.

Karthikeyan sakthivel, Renganathan narayanan developed a novel method is proposed for the early detection of glaucoma using a combination of magnitude and phase features from the digital fundus images (Karthikeyan sakthivel *et al*, 2015). Local binary patterns (LBP) and Daugman's algorithm are used to perform the feature set extraction. Local Binary Patterns (LBP) is a non-parametric operator that describes the local spatial structure of an image. At a specified pixel position (xp , yp) , it is defined as an ordered sequence of binary comparisons of pixel intensities between the pixel which is placed at the center and the surrounding pixel.Daugman's algorithm depends on the integral differential operator to the calculation of the iris and the pupil contour. Local Binary Patterns (LBP) and Daugman's algorithm are applied as a preprocessing step prior to the computation of histogram features. The histogram features are computed for both the magnitude and phase components. The histogram features are retrieved using LBP and Daugman's algorithm.The Euclidean distance between the feature vectors are analyzed to predict glaucoma.

Koen A. Vermeer , Frans M. Vos, Barrick Lo, Qienyuan Zhou, Hans G. Lemij, Albert M. Vossepoel, and Lucas J. van Vliet presented a new method to model the change in images acquired by Scanning laser polarimetry, for the detection of glaucomatous progression (Koen A. Vermeer *et al*,2006). The model is based on image series of 23 healthy eyes and incorporates colored noise, incomplete cornea compensation and masking by the retinal blood vessels. This method based on Student's-tests, morphological operations and anisotropic filtering. First, images of normal, stable eyes are analyzed to build a model of the images, describing several statistical properties of these images. Then, a method is defined to synthesize images with known types and amounts of glaucomatous progression. At each visit of a patient, three images of an area are acquired per eye. These images are split into an average image. The blood vessels in the images are extracted and used as landmarks for registration. The registration is based on a multi-level minimization of a distance metric by the Marquardt-Levenberg algorithm. The distance metric is defined by the exclusive or of the baseline blood vessel mask and the registered mask. All pixels inside the ONH and the pixels on blood vessel locations are considered ineligible because they do not reflect valid NFL measurements. The images simulated by the model are visually pleasing, show corresponding statistical properties to the real images and are used to optimize the detection methods.

Summary

Methodology	Algorithm Used	Advantages	Disadvantages
Automated Diagnosis of Glaucoma Using Empirical Wavelet Transform and Correntropy FeaturesExtracted from Fundus Images	Empirical Wavelet Transform (EWT)	Higher classification accuracy. Less Expensive	Fails to predict the level of disease.
Automated Diagnosis of Glaucoma Using Texture and Higher Order Spectra Features	Histogram equalization and radon transform	This method offers good noise immunity and yields good results. Novel features are clinically significant.	The number of diverse training images is less.
Optic Disc and Optic Cup Segmentation for Glaucoma Screening	superpixel classification	This method gives high accuracy .	The main challenge in cup segmentation is to determine the cup boundary when the pallor is nonobvious or weak.
A Framework for Detecting Glaucomatous Progression in the Optic Nerve Head (ONH) of an Eye Using Proper Orthogonal Decomposition (POD)	suprathreshold cluster tests	This method gives high performance and accuracy	TCA method is sensitive to any topographic misalignments. Increase in error probability is likely due to the images with lower resolution.
Data Mining Technique for Automated Diagnosis of Glaucoma	Higher Order Spectra (HOS) and Discrete Wavelet Transform	This method gives high performance and accuracy of 95%. This method gives highly effective and accurate tool to differentiate images.	This method not achieves a clinically important progression predictor
Wavelet-Based Energy Features for Glaucomatous Image Classification	2-D discrete wavelet transform	This method yield higher accuracy of 93% using tenfold cross validations This method yield higher efficiency	This method is very expensive
Glaucoma risk index: Automated Glaucoma Detection from Color Fundus Images	appearance-based dimension reduction technique	GRI achieves a competitive and reliable detection performance	The GRI only provides a general statement, but does not indicate conspicuous retinal regions that might hinder its acceptance in clinical environment
Decision Support System for the Glaucoma using Gabor Transformation	Gabor transform	The number of false positive is very less. This method yielded the highest performance	The accuracy of the proposed system may fall with increase in the number of images
Automated Diagnosis of Glaucoma Using Digital Fundus Images	Artificial Neural Network	This method is important to diagnose glaucoma as early as possible to minimize the damage to the optic nerve	This method clinically not important.
An Automated Detection of Glaucoma using Histogram Features	Local binary patterns (LBP) and Daugman's algorithm	The system can be used for clinical applications. It saves more time to detect the disease to take the preventive measures at earlier stage.	Can not choose the best feature extraction.
Modeling of Scanning Laser Polarimetry Images of the Human Retina for Progression Detection of Glaucoma	Marquardt-Levenberg algorithm.	This method improves the sensitivity without adversely affecting the specificity	Diminishes the need for time-consuming

CONCLUSION

This survey paper provides different techniques for the early detection of the Glaucoma which causes eye sight .There are no symptoms that able to detect the glaucoma in the early stage. Many automated detection techniques have been proposed for the glaucoma detection This research survey paper present many works related to automated glaucoma detection. Lowering eye pressure in glaucoma's early stages slows down the progression of the disease and helps save vision Through the extensive literature review carried out it has been observed that though various methods for detection of glaucoma havebeen carried out there is still a need and scope to develop a Computer Aided System which can not only help diagnose Glaucoma but would also help in checking the progression of the disease so that its growth can be restricted if not prevented. 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, 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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