REVIEW ON IMAGE PROCESSING TECHNIQUES FOR OPTIC DISC SEGMENTATION

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ABSTRACT: The review paper describes various image processing techniques for optic cup and disc segmentation for automatic detection of glaucoma. Glaucoma is one among major causes of blindness in working population. Early detection of Glaucoma through automated retinal image analysis helps in preventing vision loss. The end-to-end processing pipeline for Glaucoma detection from retinal images includes the detection of optic disc (OD), neuroretinal rim (NRR), and optic cup (OC) segmentation, feature computation from the segmented OD and OC, and estimation of Glaucoma from these features. Optic disc (OD) segmentation from retinal images is the preliminary step in developing the diagnostic tool for early Glaucoma detection. The segmented OD is preprocessed to highlight the NRR and OC area. A multi-layer perceptron with 12-D feature vector is used for pixel classification based OC segmentation. Cup-to-disc ratio and other contextual features are extracted from the segmented OD and OC. Experimental evaluation shows that the proposed methodology can be reliably utilized in screening programs for early glaucoma detection.

INTRODUCTION:
Automated Image analysis and processing is of great significance in early detection, screening and treatment planning of various retinal, ophthalmic and systemic disease especially because if its non-invasiveness. Precise detection and accurate analysis of ophthalmic pathologies for timely treatment is essential in preventing vision loss. The development of Computer Assisted Diagnostic (CAD) systems for assisting the clinicians in diagnosis and prognosis of retinal diseases has a vital role in improving the healthcare, particularly in the developing countries with shortage of professional ophthalmologists. Accurate localization and precise segmentation of optic disc (OD) is the first step in developing CAD systems for early detection of ophthalmic diseases like Glaucoma and
diabetic retinopathy. Glaucoma is causing visual loss and blindness around the globe at second highest rate. The Glaucoma patients are mostly ignorant at early stages about the effects until visual loss progress and over the 5-year period, damage to optic nerve fiber increases to 63%. The increased intraocular pressure within the eye damages the optic nerve through which retina sends light to the brain where they are recognized as images and makes vision possible. Because revitalization of the degenerated nerve fibers of the optic nerve is impossible early detection of the disease is essential. The optic nerve head is the location connecting the optic nerve and retina. The optic nerve head consists of an optic disc, cup and neuroretinal rim (NRR) as shown in Figure 1. Moreover, the progression in optic nerve fiber damage causes the structural changes in OD, optic nerve head and nerve fiber layer which results in an increase in optic Cup to Disc Ratio (CDR). The CDR can be accessed by estimating the diameter and the area of OD, the area of rim and optic cup diameter. The accurate and fast OD segmentation and analysis is the first step towards the development of computer assisted diagnostic system for Glaucoma screening in large population based studies.

![Figure 1](image_url)
Figure 1. Fundus image depicting the optic cup, Neuroretinal rim (NRR) and optic disc.

**OPTIC DISC SEGMENTATION:**

Different techniques are described in the literature for OD segmentation and optic cup extraction for the computation of CDR. Table 1 shows the various methods used for segmentation of optic disc with its accuracy. For the segmentation of OD boundary, the first step is to approximate the OD center. Optic disc appears as the
brightest spot in the retinal fundus images but the presence of artifacts can create multiple bright spots. Pathologies in fundus images can take shape of OD while actual OD could lose its brightness. The shape of the OD varies from circular to elliptical. This information about the shape of the OD can be used for the detection of OD. CHT is used for OD localization. The second step is to identify the NRR region and segmentation of optic cup. The third step is the extraction of contextual features which includes computation of CDR and ISNT and the final step is to estimate the Glaucoma based on these features.

Tzolkin Garduno-Alvarado et.al [1] proposed the identification of the optic disc (OD) in fundus images is a useful landmark for a large number of ophthalmic diseases. The method proposed here in detects and segments the OD in a rather simple and fast manner, compared with those methods recently published. The procedure involves first: segment the blood vessel, then locate the OD using the highest intensity values found near the vessels. Finally, OD segmentation is performed using a modification of the elliptical Hough transform. The results are evaluated using five different metrics already used in the literature on the subject, and applied to a public database of 1200 fundus images, obtaining 89% in the Dice coefficient and 82% in Jaccard coefficient, and taking a processing time of 4.1 seconds per image. Compared with other published methodologies, the results presented with the current technique, improve speed performance while maintaining similar precision metrics.

Suddha Shakthi Goutam Ashe et.al [2] is based on the rapid growth of the silent Killer, diabetes, is a major reason of concern for health and also started a buzz among our society. Though, diabetes is not completely curable but early stage detection can helps in controlling the degree of severity of this silent killer. One of the controlling Factors, which could help in early detection, is the retina of the eye, a light sensitive metabolically active region on which non invasive observation can possible. In this paper, intensity based preprocessing algorithm which is suitable for the detection of optic disc (OD) and macula before the analysis of diabetic retinopathy is proposed. Optic Disc is a region on the retina with high intensity values and macula a region of
low intensity values. The threshold is decided with the help of Gaussian Distribution. The threshold equation is given by,

$$th = \mu + \left\{ \sqrt{2\log(p\sqrt{2\pi\sigma^2})} \right\} \ast \sigma$$

The proposed algorithm is evaluated over a set 100 fundus images obtained from Messidor database.

J.Cheng et.al [3] proposed the retinal fundus photographs have been used in the diagnosis of many ocular diseases such as glaucoma, pathological myopia, age-related macular degeneration and diabetic retinopathy. With the development of computer science, computer aided diagnosis has been developed to process and analyse the retinal images automatically. Here, we approximate the degradation of the retinal images as a combination of human-lens attenuation and scattering. A novel Structure-preserving Guided Retinal Image Filtering (SGRIF) is then proposed to restore images based on the attenuation and scattering model. The proposed SGRIF consists of a step of global structure transferring and a step of global edge-preserving smoothing.

X.Wu et.al [4] proposed the reliable localization of the Optic Disc (OD) is important for retinal image analysis and ophthalmic pathology screening. This paper presents a novel method to automatically localize ODs in retinal fundus images based on directional models. According to the characteristics of retina vessel networks, such as their origin at the OD and parabolic shape of the main vessels, a global directional model, named the relaxed biparabola directional model, is first built. Then, a local directional model, named the disc directional model, is built to characterize the local vessel convergence in the OD as well as the shape and the brightness of the OD. Finally, the global and the local directional models are integrated to form a hybrid directional model, which can exploit the advantages of the global and local models for highly accurate OD localization.

Shuang Yu et.al [5] was the automatic detection of neovascularisation in the optic disc region (NVD) for colour fundus retinal image is presented. NV is the indicator for the onset of Proliferative Diabetic Retinopathy (PDR) and it is featured by the presence of new vessels in the retina. The new vessels are fragile and pose a high risk for sudden vision loss. Therefore, the importance of accurate and timely detection of NV cannot be
underestimated. An automatic image processing procedure for NVD detection that involves vessel segmentation using multi-level Gabor filtering, feature extraction of vessel morphological features and texture features, and image classification with support vector machine. 42 features are extracted from each NVD image and feature selection procedure further reduce the optimal feature dimension to 18.

Kemal Akyol et.al [6] proposed the advances in the computer field, methods and techniques in automatic image processing and analysis provide the opportunity to detect automatically the change and degeneration in retinal images. Localization of the optic disc is extremely important for determining the hard exudate lesions or neovascularization, which is the later phase of diabetic retinopathy, in computer aided eye disease diagnosis systems. Sometimes information related to optic disc and hard exudate information may be the same in terms of machine learning.

Lamia AbedNoor Muhammed [7], the author proposed the examination of retinal image continuously plays an important role in determining human eye health; with any variation present in this image, it may be resulting from some disease. Therefore, there is a need for computer-aided scanning for retinal image to perform this task automatically and accurately. The results of practical work were obtained using different common data set, which achieved good accuracy in trivial computation time. Finally, this paper consists of four sections: a section for introduction containing the related works, a section for methodology and material, a section for practical work with results, and a section for conclusion.

Santhananukumar.R et.al [8] was that Diabetic retinopathy is the most general diabetes complication that affects eyes and results in blindness. It's due to impairment of the arteries a veins located in the fundus of eye (retina) that are composed of light sensitive tissues. In patch level prediction algorithm will localize the diseased region in the Diabetic Retinopathy image like Hard Exudates and Hemorrhage. The patch level classification uses Support Vector Machine (SVM) machine learning classifier model to predict the potential patch of Hard Exudates and Hemorrhage. In this algorithm, the image is broken into regular rectangular patch. The classifier model is built on training dataset and tested against the test dataset.
Andrea Giachetti et.al [9] proposed a complete pipeline for the detection and accurate automatic segmentation of the optic disc in digital fundus images. This procedure provides separation of vascular information and accurate inpainting of vessel-removed images, symmetry-based optic disc localization, and fitting of incrementally complex contour models at increasing resolutions using information related to inpainted images and vessel masks. Validation experiments, performed on a large dataset of images of healthy and pathological eyes, annotated by experts and partially graded with a quality label, demonstrate the good performances of the proposed approach. The method is able to detect the optic disc and trace its contours better than the other systems presented in the literature and tested on the same data. The optic disc segmentation pipeline is currently integrated in a complete software suite for the semiautomatic quantification of retinal vessel properties from fundus camera images (VAMPIRE).

B.S.A.Kumar et.al [10] proposed the optic disc disjuncture that starts by defining the location of the optic disc. This progression used the union feature of vessels into the optic disc to estimate its location. The disc area is then subdivided using two different automated methods (MRF image reconstruction and compensation factor). Both methods use the convergence feature of the vessels to identify the position of the disc. The MRF method is applied to eliminate the vessel from the optic disc region. This process is known as image reconstruction and it is performed only on the vessel pixels to avoid the modification of other structures of the image. On the other hand, the reimbursement factor incorporates vessels using local intensity characteristics to perform the optic disc disjuncture. Thus, this method can be applied in other medical image analysis applications to overcome “the overlapping tissue disjuncture.” The potential investigate will be based on the disjuncture of retinal diseases (lesions) known as “exudates” using the sub divided structures of the retina (blood vessels and optic disc).

Sandra Morales [11] is mainly based on mathematical morphology although includes a principal component analysis (PCA) in the preprocessing stage. The main steps of the method are the following: First, the PCA is applied on the RGB fundus image in order to obtain a grey image in which the different structures of the retina, such as vessels and
OD, are differentiated more clearly to get a more accurate detection of the OD. Next, a variant of the watershed transformation, the stochastic watershed transformation, followed to a stratified watershed, are implemented on a region of the original image. The final goal of the proposed method is to make easier the early detection of diseases related to the fundus. Its main advantage is the full automation of the algorithm since it does not require any intervention by clinicians, which releases necessary resources (specialists) and reduces the consultation time, hence its use in primary care is facilitated.

Chuang Wang et.al [12] represents the template matching method used to locate the approximate optic disc centre. There are two main stages for the optic disc centre detection: (1) template matching, and (2) relocating the optic disc centre. The segmentation using the grey level image Fodcr, which contains all the information necessary. However, the high contrast of the blood vessel inside the optic disc misguides the segmentation energy functional and breaks the continuity of the optic disc boundary. Therefore, the morphological closing operation is applied to remove the blood vessels, and the vessel removed image (Fvr) is obtained. The proposed method was evaluated on three public datasets, the DRIVE [27], the DIARETDB0 [28] and the DIARETDB1 [29], with a total of 259 images. First, the template matching method is used to approximately locate the position of the optic disc. After that, the Level Set Method incorporated with shape-prior term, distance-regularization term and edge-based term is used to segment the optic disc.

Reshmi Panda et.al [13] describes the proposed CTCRW algorithm for accurate OD segmentation. In the first step, blood vessel inpainting and intensity adjustment is performed. The mean curvature feature, Gabor energy texture feature and intensity features are then extracted and used to compute the weights for the proposed CTCRW algorithm. After selecting the background and foreground seed pixels, the solution to combinatorial Dirichlet problem minimisation is computed to get the probability of unmarked pixels belonging to the seed pixels. The CTCRW algorithm is shown to segment OD more accurately by incorporating the mean curvature and Gabor texture energy information in the composite edge weight function.

P.C.Siddalingaswamy et.al [14] is where the boundary of optic disc is located in two steps approach. First, the approximate center of optic disc is detected in the retinal
image using iterative thresholding method followed by connected component analysis.

Digital colour retinal images required for the automated optic disc segmentation were provided by the Department of Ophthalmology, Kasturba Medical College, Manipal. The images are captured using a Sony FF450IR digital fundus camera. A total of 148 images with resolution of 768 x 576 in 24 bit JPEG format are used. Based on the result obtained in optic disc boundary detection, it can be stated that geometric based implicit active contour models provide a better segmentation for images with weak boundaries when compared to parametric models.

M. Forocchia et al [15] proposed method is based on a model of the geometrical directional pattern of the retinal vascular system, which implicitly embeds the resulting method is not just based on the detection of the area of convergence of vessels, but rather on the fitting of a model with respect to the entire vascular structure. The performances of the proposed method, based on a model of the vascular structure, are dependent on the availability of a good portion of this structure in the image, whereas are independent of the actual visibility (or even presence) of the OD. However, the remarkably good results obtained using the data provided by either procedure used in this work, which were algorithmically different and independently developed, suggest that this is not a critical issue.

Brindha T. Sambandam et al [16] segments the optic disc and optic cup using Krill Herd algorithm and compared the performance results with other state of the art methods by using Seed based region growing and Active Contour Segmentation. The algorithm used in this paper achieves superior accuracy for OD detection, yields better performance for OD segmentation and low computation time to segment the OD over the existing methods reviewed in literature. Krill Herd (KH) algorithm is one of the most recent swarm based algorithms simulating the herd behavior for each krill individual.

KH algorithm works to find the minimum distance of the krill individual from pixels with the highest intensity. It has been successfully applied in many optimization areas such as numerical optimization, electrical and power system neural network breast cancer detection and graph based network route. This algorithm has been tested on 1000 databases and has produced an accuracy of 96.8% with less computation time over the
existing methods.

Amin Dehghani et.al [17] instead of creating an image as template, three histograms as template are constructed, each corresponding to one color component. At the first step to decrease the effect of noise, an average filter with the size of $6 \times 6$ pixels has been applied to retinal images. Then, a window with the typical size of the optic disc ($80 \times 80$ pixels) to extract the optic disc of each retinal image is used. In the next step, color components (red, blue, and green) of each optic disc is separated to obtain the histogram of each color component. Finally, the mean histogram of each color component for all retinal image samples is calculated as template. Then, to decrease the effect of pathological regions and exudates that are high-bright regions like optic disc, the histogram of pixels is used which has the intensity value lower than 200. Deepali A.Godse et.al [18] presents a novel algorithm for OD localization. The proposed algorithm ensembles the steps based on different principles and produces more accurate results. Applying this threshold, all bright regions within image called clusters are detected. Then two different criteria on these clusters are applied, a: area criterion and b: density criterion. As the OD and its centre are located accurately, macula and its centre can be detected accurately. OD, macula and vascular network are unique anatomical structures of retinal image. So centre of OD, centre of macula and bifurcation points of vascular network can be used as control points for registration of retinal images. The accurate registration of retinal images can be further used for retinal image change detection and super-resolution.

Ana Salazar Gonzalez et.al [19] is the optic disc segmentation process where the convergence feature of vessels into the optic disc region is used to estimate its location. Two automated methods [Markov random field (MRF) image reconstruction and compensation factor] are used to segment the optic disc. The disc area is then segmented using two different automated methods (MRF image reconstruction and compensation factor). The MRF method is applied to eliminate the vessel from the optic disc region. This process is known as image reconstruction and it is performed only on the vessel pixels to avoid the modification of other structures of the image. In contrast to MRF method, the compensation factor approach segments the optic disc using prior local intensity knowledge of the vessels.
Carmen Alina Lupascu et.al [20] proposed the optic disc in the color retinal images which appear as a bright region. The appearance of the optic disc is characterized by a rapid variation in intensity of adjacent pixels. The variance was used in our algorithm for the recognition of the optic disc. A color fundus image have a dark background. The pixels with the maximum intensity within the green plane (the green plane has been used because it shows the optic disc with highest contrast) of the image were searched (except some cases the pixels having maximum intensity are situated inside the optic disc). Starting from this initial point eight 'directions’ are considered: one direction for each 45 degrees in counter-clockwise. In each direction three points of interest are chosen (the ones for which there is a rapid variation in intensity with the adjacent pixel in that direction). The mean of all these distances was computed. Those points of interest having a distance major than this mean were excluded for future validations.

Table 1: Quantitative results of the various methods.

| S.No | Authors                        | Technique                                      | Dataset              | Number of images | Accuracy (%)
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<tbody>
<tr>
<td>1</td>
<td>Tzolkin Garduno-Alvarado et.al</td>
<td>Ellipical Hough Transform</td>
<td>MESSIDOR</td>
<td>1200</td>
<td>99</td>
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<tr>
<td>2</td>
<td>Suddha Shakthi Goutam Ashe et.al</td>
<td>Gray channel and Threshold selection</td>
<td>MESSIDOR</td>
<td>50</td>
<td>82</td>
</tr>
<tr>
<td>3</td>
<td>J.Cheng et.al</td>
<td>SGRIF</td>
<td>ORIGA</td>
<td>650</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>X.Wu et.al</td>
<td>Directional models</td>
<td>STARE ARIA MESSIDOR</td>
<td>81 120 1200</td>
<td>100</td>
</tr>
<tr>
<td>5</td>
<td>Shuang Yu et.al</td>
<td>Machine learning</td>
<td>Kaggle</td>
<td>424</td>
<td>95.23</td>
</tr>
<tr>
<td>6</td>
<td>Kemal Akyol et.al</td>
<td>Bright region, Keypoint detection, Visual dictionary</td>
<td>DIARETDB1 DRIVE ROC</td>
<td>100</td>
<td>90</td>
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<td>7</td>
<td>Lamia AbedNoor Muhammed</td>
<td>Entropy based algorithm</td>
<td>Medical Image and Signal Processing Research Center</td>
<td>35</td>
<td>100</td>
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<td>8</td>
<td>Andrea Giachetti et.al</td>
<td>Free form contour</td>
<td>MESSIDOR</td>
<td>1200</td>
<td>83</td>
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<tr>
<td></td>
<td>Authors</td>
<td>Methodology</td>
<td>Databases</td>
<td>Accuracy</td>
<td>Impact Factor</td>
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<tr>
<td>9</td>
<td>Sandra Morales</td>
<td>Mathematical morphological with PCA</td>
<td>DRIONS ONHSD MESSIDOR</td>
<td>110</td>
<td>99.47</td>
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<td>10</td>
<td>Chuang Wang et al</td>
<td>Level set method</td>
<td>DIARETDB1 DIARETDB0</td>
<td>89</td>
<td>98.48</td>
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<td>11</td>
<td>Reshmi Panda et al</td>
<td>CTCRW</td>
<td>DRIVE DRISHTI-GS DIARETDB1 MESSIDOR</td>
<td>40 101 89 1200</td>
<td>-</td>
</tr>
<tr>
<td>12</td>
<td>P.C. Siddalingaswamy et al</td>
<td>Implicit active contours</td>
<td>Department of Ophthalmology, KMC, Manipal</td>
<td>148</td>
<td>99.3</td>
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<td>13</td>
<td>M. Foracchia et al</td>
<td>Geometrical vessel structure</td>
<td>STARE</td>
<td>81</td>
<td>98</td>
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<td>14</td>
<td>Brindha T. Sambandam et al</td>
<td>Krill Herd Algorithm</td>
<td>Local hospital</td>
<td>1000</td>
<td>96</td>
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<td>15</td>
<td>Amin Dehghani et al</td>
<td>Histogram Matching</td>
<td>Local database</td>
<td>273</td>
<td>96.75</td>
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<td>Deepali A. Godse et al</td>
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<td>Local database DIARETDB0</td>
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<td>MRF Algorithm</td>
<td>DIARETDB1</td>
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<td>95</td>
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<td>Carmen Alina Lupascu et al</td>
<td>Circular Hough Transform</td>
<td>DRIVE</td>
<td>40</td>
<td>95</td>
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CONCLUSION:
Researchers have focused on localization of optic disc using a computer, so more methods have been suggested with good results. In spite of this, the proposed algorithm in this paper gives significant results through simple computational steps that are executed in a short period of time. The correct and precise segmentation of the Optic Disc will increase the correct diagnosis. Moreover, the algorithm entails a simple technique, so it can be combined with other algorithms in order to be more effective as a supporting step. With the improvement in time efficiency, the proposed methodology can be used as a building block in developing an automated system for early detection of eye diseases caused due to defects in optic disc. This review paper depicts many works related to localisation and segmentation of optic disc using various methods.

REFERENCES:


