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A Survey on Optic Disc and Fovea Segmentation

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Abstract: Digital retinal images are widely used for early detection of retinal, ophthalmic and systemic diseases because they provide a non-invasive window to the human circularity system and associated pathologies. Automated retinal image analysis is becoming an important screening tool for early detection of certain risks and diseases like diabetic retinopathy, hypertensive retinopathy, age related macular degeneration, glaucoma etc. This in turn can be used to reduce human errors or to provide services to remote areas. Optic disc localization and segmentation in digital fundus images may seem an easy task, due to the fact that the optic disc appears in most of the images as the brightest spot, approximately circular. Hence a number of algorithms and techniques are being developed for its segmentation. This paper reviews and compares the algorithms and techniques anteriorly proposed in order to develop better and more efficacious techniques and algorithms for detection of optic disc and fovea.

Keywords: Optic Disc, Fovea, Retinal images, Fundus image, Segmentation, Image processing.

I. INTRODUCTION

Medical image analysis is an important tool in thefield of medicine. It has got great significance in processing and analysing medical issues using various imaging modalities. Fundus image analysis has become vital in ophthalmological field. Image segmentation is a process by which an image is segmented into salient regions mostly based on their pixels.it acts as a tool for the easier analysis of the image. It subdivides an image into its constituent region and the extent of subdivision depends on the objects of interest in an application have been isolated. ie; the result of image segmentation is a set of segments that extracted from the image which is subjected for analysis. The accuracy of image analysis depends on the performance of image segmentation. Several methods exists for image segmentation. In retinal image analysis the major concern is for the segmentation of optic disc and fovea. The retina is a light-sensitive layer at the back of the eye that covers about 65% of its interior surface. In the middle of the retina is a small dimple called the fovea or fovea centralis. It is the centre of the eye's sharpest vision and the location of most colour perception. The Optic Disc (OD) is the brightest part in normal fundus retinal images. It is the region of entrance of blood vessels and optic nerves to the retina and it works as a landmark to other features in the retinal fundus image. An efficient detection of optic disc and fovea is a significant task in an automated retinal image analysis system. Analysis of optic disc and fovea helps in the diagnosis of ophthalmic diseases. Several methods has been proposed for the localization and segmentation of optic disc and fovea. Methods like thresholding, clustering, histogram based, level set, etc. are some of them.

In this review paper we have done detailed survey on more than 70 papers on optic disc and fovea segmentation. From the detailed study that we made, the different methods of retinalimage analysis, different steps involved, its pros and cons were understood.

A. Eye structure

1) Retina :

-Nerve layer that lines the back of the eye.

-Senses light, and creates impulses that travel through the optic nerve to the brain

2) Retinal Fundus :

-Interior lining of the eyeball

-Includes the optic disc and the macula

3) Optic disc :

-Brightest part in normal fundus retinal images

-Region of entrance of blood vessels and optic nerves to the retina.

-Works as a landmark to other features in the retinal fundus image.

4) Macula :

-Small spot where vision is keenest

-At the center of the retina

5) Fovea :

-Centre most part of the macula

-Crucial for reading, watching, driving etc.

B. Segmentation

The goal of image segmentation is to cluster pixels into salient image regions, i.e., regions corresponding to individual surfaces, objects, or natural parts of objects [1]. Its goal is to simplify and change the representation of an image into something that is more meaningful and easier to analyse. It subdivides an image its constituent region or objects. The level to which the subdivision is carried depends on the problem being solved [2]. That is segmentation should stop when the objects of interest in an application have been isolated. Its accuracy determines the eventual success or failure of computerized analysis

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procedures. Image segmentation is typically used to locate objects and boundaries in images. The result of image segmentation is a set of segments that collectively cover the entire image, or a set of contours extracted from the image. Image segmentation algorithms generally are based on one or two basic properties of intensity values; discontinuity and similarity .In the first category the approach is to partition an image based on abrupt changes in intensity such as edges in an images [2]. The principle approach in second category are based on partitioning image into regions that are according to set of predefined criteria.

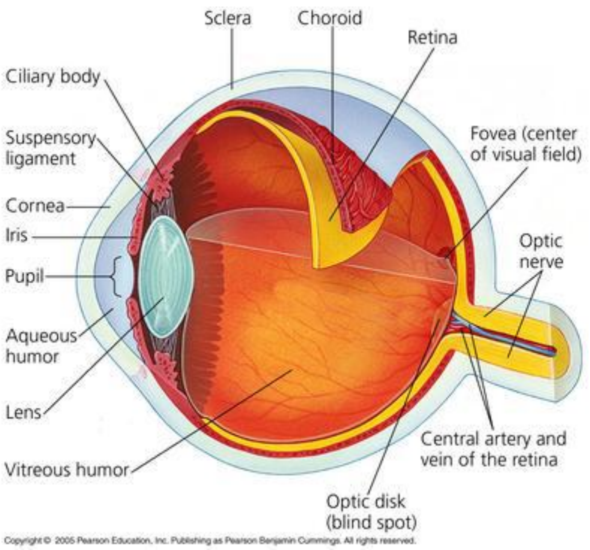

Fig 1: Human Eye Structure (courtesy:https://ccbbiology10.wikispaces.com/Grade+10+1.5+The+Eye?responseToken7a54254954c9c47fbf5d76febee40d81, January 26, 2017, Time:1:57pm)

II. REVIEW OF METHODS

In the paper authored by Jun Cheng et al.[3], a super pixel classification method is used which uses histogram of super pixels from the contrast enhanced pictures. The unbalanced cluster issue caused due to per papillary atrophy is avoided by using bootstrapping in the training also it is important to have a good initialization in deformable model based optic disc segmentation. The method was tested on a database of 650 images and a self-assessment reliability score was calculated. The results showed an overlapping error of 10.0% and standard deviation of 7.5%.

The paper by SumanSedai et al.[4] provides a method for the accurate segmentation of optic disc in retinal colour fundus images using an automatic regression based method. The approximated optic disc obtained after segmenting using circular Hough transform is used to compute the initial cup shape. The method of regression analysis is a statistical process for estimating the relationships among variables and the cascaded shape regression method iteratively learns the final shape of the optic cup and disc from an initial shape. Gradient boosted regression trees are employed to learn each regressor in the cascade. The proposed method provided high segmentation accuracy for optic cup and disc segmentation with dice metric of 0.95 and 0.85.

The paper by JunjieBai et al.[5] presents a graph based method which simultaneously segment multiple star-shaped surfaces. Minimum and maximum surface distance constraints can be enforced between different surfaces. The surface smoothness constraints that limits the variations of adjacent voxels, made the segmented surface smooth. A single min s-t cut graph was constructed since the problem was considered as an MRF optimization problem. In order to make sure the segmentation result is star-shaped and consistent, a consistent digital ray system was utilized. The method is applied to the segmentation of the optic disc and cup on 70 registered fundus and the result shows improved accuracy by applying the proposed method.

HandayaniTjandrasa, Ari Wijayanti, NanikSuciati[6] proposed a method to detect optic nerve head based on the Hough Transform and Active Contour Models. Retinal images for evaluation were obtained from the DRIVE database. The method has reported an accuracy of 75.56% using 30 images.

Huiqi Li and Opas Chutatape[7] proposed a novel method to detect the optic disc. In this method principal component analysis is used for localization of Optic disc. A modified active shape model (ASM) is proposed to detect the disc boundary. The proposed method has achieved success rates of 99%, 94%, and 100% for disc localization, disc boundary detection, and fovea localization respectively. The image for analysis was obtained from the Singapore National Eye Center (SNEC).

H Yu, S Barrigab, C Agurtoa, S Echegarayb, M Pattichisa, G Zamorab, W Baumanc and P Solizb[8] proposed an approach for the optic disc localization using template matching and directional matched filter. A fast hybrid level-set algorithm was proposed to segment the optic disc boundary. The method uses both the region information and object boundary with simple initialization. The image for analysis is obtained from the MESSIDOR with 1200 images. The OD location methodology obtained 98.3% success rate, while fovea location achieved 95% success rate.

Adithya and Nanik[9] proposed a method that makes use of k-means clustering and adaptive morphology method for optic disc segmentation which has not been used before. Here the area of the optic disc is found out by using the k-means clustering method so that the segmentation would be more precise. Segmentation is done by using the adaptive morphology. The cutting of blood vessels results in the lack of clarity in the area of the blood vessel, also some veins are truncated when segmentation are the disadvantages of this method. The

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execution of this paper uses a database of drive and implementation of methods using Matlab.

The level set method proposed by Chuang Wang and DjibrilKaba [10] is the segmentation of an image by solving a partial differential equation. After the localization of optic disc, the blood vessel is extracted to reset the centre followed by level set method, which incorporates edge term, distance-regularization term and shape-prior term, to segment the shape of the optic disc. Seven measures are used to evaluate the performance of the methods. The effectiveness of the proposed method is evaluated against alternative methods on three public data sets drive, diaretdb1 and diaretdb0. The advantages is that it is implicit, parameter-free, provides a direct way to estimate the geometric properties of the evolving structure, allows for change of topology, and is intrinsic. The method provided an average sensitivity of 94.65%, average specificity of 98.89%, average predictive value of 93.95% over DIARETDB0 dataset and average sensitivity of 93.24%, average specificity of 98.94%, average predictive value of 94.23% over DIARETDB1 dataset and average sensitivity of 92.58%, average specificity of 99.26%, average predictive value of 95.19% over DRIVE dataset.

The method suggested by ShabanaMol, Deepa and Jubilant [11] is under the assumption of the homogeneity of images; that is the image is modelled as a weighted graph. Then the images are partitioned under certain criterion. The expectation maximization method is also known as maximum a posteriori estimation method which is an iterative procedure where the approach is to find a function for the expectation (E) of the log-likelihood evaluated using the current estimate for the parameters, and maximization function (M) which computes parameters maximizing the expected log-likelihood found on the e step. These two steps iterates alternatively. The method has an accuracy of 95.13%, TPR of 87.17% and FPR of 3.64%.

Marc Lalonde ,Mario and Langis Gangnon[12] proposed a method using pyramidal decomposition and Hausdorff-Based Template Matching. The potential regions which might contain the optic disc are first found by means of a pyramidal decomposition on the gray scale representation of the input colour image.Then the search for the OD contour is performed using an algorithm based on the Hausdorff distance. The key idea is that the areas identified by the pyramidal decomposition method are explored for the presence of a circular shape, as if the OD was a symbol in a map. An average error of 7% on OD centre positioning is reached with no false detection.

Vasanthi and group [13] proposed a model that presents an automated glaucoma detection method known as colour fundus imaging (CFI) and gradient vector flow (GVF) to extract OD boundary. To overcome the problem of over segmentation, Chan-Vese (C-V) model is proposed including local image information. The second is to localize OD region and define region of interest for further processing. The contour initialization is done through circular Hough transform. To avoid the possible noise, Gaussian nose filter is used and then disc boundary detection is used through gradient vector flow model whose performance relies on contour initialization. The comparison results showed that the method is more robust and accurate than the other model, particularly in the cases of atrophy.

Giraddi and Dr.JagadeeshPujari[14] suggested the application of GVF snakes for automatic optic disc detection. The initial snake was placed after finding a largest patch of optic disc by a recursive region growing algorithm. They have evaluated their proposed algorithm of optic disc localization and contour detection on two popular research databases of colour retinal images: DIARETDB0 and DIARETDB1. This algorithm was able to detect the optic disc in 125 images. For evaluation they performed optic disc detection with Hough transform also. After evaluation, it was found that the proposed algorithm was considerably better than Hough transform which fails to detect disc when the optic disc edge is not clear due to interference of blood vessels. This method has given sensitivity of 93% and specificity of 95%.

The paper by AmandeepKaur and ReechaSharma[1] discusses the automatic segmentation of the optic disc from a fundus image. For the detection of the optic disc, its approximate position is found. Then the exact contours are found by means of the watershed transformation. This method for the extraction of the optic disc contour is mainly based on mathematical morphology along with thresholding and watershed transform.

Soumitra Samanta, Sanjoy Kumar Saha and BhabatoshChanda[15] presented a simple and fast algorithm using Mathematical Morphology to find the fovea region. The proposed algorithm is based on the structure of the blood vessels and some information of the optic disc. They have tested the algorithm on a publicly available DRIVE database and have obtained comparable results with a state of the art in this area. The success rate was found to be 97.14%. They have also tested on the images of their own database containing 20 images and have achieved 100% success.

Sandra Morales and others [16] proposed a novel approach for the extraction of the optic disc based on mathematical morphology along with principal component analysis (PCA). They have used Stochastic Watershed transformation technique for grey-scale image for segmentation. The evaluation was performed on DRIONS, DIARETDB1, DRIVE, MESSIDOR and ONHSD database.

The paper proposed by AshaMerin Jose and ArunBalakrishnan [17] make use of morphological operations and hybrid level-set methodology for the optic disc segmentation. Segmentation of optic disc is done by first detecting blood vessels using SVM classifier and then

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the bending points on the circum linear vessels. Parameters such as vertical cup to disc ratio (CDR), cup to disc area ratio are calculated and used for glaucoma detection. A CDR value greater than 0.5 and cup-to- disc area ratio greater than 0.3 indicates the presence of glaucoma. The proposed method is found to produce a mean error as low as 0.021.

The paper by Deepali A. Godse and Dr.Dattatraya S. Bormane[18] presents an automated system to locate the OD and its centre in all types of retinal images. The proposed algorithm gives excellent results and avoids false OD detection. This technique was tested on standard databases provided for researchers on internet, Diaretdb0, Diaretdb1, Drive and local database collected from ophthalmic clinics. It was able to locate OD and its centre in 98.45% of all tested cases. Compared to the approaches by other researchers, this algorithm for OD detection has the advantage that it is applicable to all types of retinal images, healthy as well as abnormal, affected due to disease and/or acquisition process.

Ivo Soares et al.[19] described a very effective method based on two new techniques - the cumulative sums of successive subdivisions and the vessel enhancement. The algorithm begins with a new vessel enhancement method based on a modified corner detector and subsequently, a weighted version of the vessel enhancement is combined with morphological operators, to detect the four main vessels orientations. These four image functions have all the necessary information to determine initial optic disc localization, resulting in two images that are respectively divided along the vertical or horizontal orientations with different division sizes. Each Division is averaged creating a 2-D step function, and a cumulative Sum of the different sizes step functions is calculated in the vertical and horizontal orientations, resulting in an initial optic disc Position. The final optic disc localization is determined by a vessel convergence algorithm using its two most relevant features; high vasculature convergence and high intensity values. This method was evaluated in eight publicly available datasets, including the STARE and DRIVE datasets and reported an accuracy of 99.15% with an average computation time of 18.34 s.

In the paper proposed by Suresh Babu V, S. Vijayan, Anju Susan, NeepamRamakrishnan and Jestin V. K [20] the fovea region is detected with the help of adaptive histogram equalization, thresholding method and smoothing method. These features are preceded with the help of Fuzzy C-Means clustering algorithm to detect the Different diabetic retinopathy stages and the results are compared with KNN. The accuracy of the diabetic retinopathy Detection system is found to be 98.5%.

Paintamilselvi, Shyamala[21] used a method to detect the fovea of fundus retinal image using Mathematical Morphology. The image for analysis is obtained from the DRIVE database. The accuracy of this method is 94.42% in finding the blood vessels. Based on the image from database the location of optic disc decided. Two major algorithms are considered in analyzing it. First algorithm involves the isolation of blood vessels and next algorithm deals with the localization of fovea. The blood vessels of the disc are identified using morphological filters of matlab. To reduce correlated colour information, RGB image is converted into gray-scale. Mathematical morphology is followed by Top-Hat transformation is used to reduce the small noise. The origin of optic disc is identified based on the adaptive mathematical morphology. The fovea is located at a distance of 2.5 times the diameter of optic disc from its centre. Fovea is identified using the sliding window technique. Sliding window technique is utilized to find the gray mixed black colour fovea. This method is simple and efficient in extracting the fovea. This approach is enhanced to detect the diabetic retinopathy diseases. This method is robust also. Proposed methodology can be utilized in hospitals to detect diseases occurring in the eyes.

T. Vandarkuzhali, Aswani S. Babu and C. S. Ravichandran [22] proposed an approach for the blood vessel detection using morphological operations and geometrical functions. Algorithm of fovea localization is Adaptive histogram equalization method is utilized along with a median filtering scheme which was carry out for demising of the image. The database from LOTUS EYE HOSPITAL, Coimbatore used to evaluate the proposed algorithm.

Amin Dehghani,HamidAbrishamiMoghaddam ,MohammadShahramMoin[23] proposed a method to localize the center of optic disc by calculating the average of histograms for each colour component as template to localize the OD. The DRIVE, STARE, and local dataset retinal images are used with a success rate of 100, 91.36, and 98.9%, respectively.

Shobhana.M and S.B.Chitrapreyanka[24] proposed a simple, fast algorithm using mathematical morphology to find the fovea region. The localization of optic disc is important for two purposes. The simulation tool used for processing input colour fundus images is MATLAB.

The paper by OakarPhyo, AungSoeKhaing[25] presents the mathematical morphology method to detect and eliminate the optic disc (OD) and the blood vessels. Optic disc and the blood vessels are detected and eliminated by using mathematical morphology methods such as closing, filling, morphological reconstruction and Otsu algorithm. It is a faster method hence can process within a few minutes. Also this technique can work effectively even on a poor computer system. Therefore this method is suitable for rural area in developing countries. The input images are taken from the websites and "Eye and ENT General Hospital (Mandalay).

A new approach has been proposed by Jeetinder Singh, Jayanthi Sivaswamy [26] to extract fovea region automatically and robustly. The OD is localized based on pyramidal decomposition and Hausdorff-distance based

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template matching. Based on the domain knowledge they present an algorithm for detecting the fovea. The image for analysis is obtained from the STARE: Structured Analysis of the Retina. LVPEI: L V Prasad Eye Institute. An overall accuracy of 90.57% is reported. The method fails if fovea regionfails to satisfy maximum sized dark region selection constraint and also if the red channel is highly saturated and fails to capture fovea region.. Also the results show that the localization of fovea can be used as seed point for the detection of other anatomical landmarks.

H ANugroho, L Listyalina, N A Setiawan, S Wibirama, D A Dharmawan [27] came up with a method in which the red channel is extracted as the first step of automatic segmentation. Then, the OD area is localized using circular average filter to detect the candidate OD point for establishing the region of interest (ROI). Then multiple bottom hat transformation is employed to detect the blood vessels. To remove blood vessel regions, the result of multiple bottom hat transformation is added to ROI image. The method is tested on forty different optical disc images from DRION database. Average level of sensitivity, specificity and accuracy of 96.12%, 94.36% and 94.71%, respectively are achieved. This indicates that the proposed algorithm successfully detects and segments the optic disc area and is able to be implemented as measurement for the projection line to get the centre of the fovea.

A new methodology for detecting the fovea center position in digital retinal images was presented by Manuel E. Gegundez-Arias, Diego Marinb, Jose M. Bravob, Angel Suerob[28]. A pixel is firstly searched for within the foveal region according to its known anatomical position relative to the optic disc and vascular tree. Then, this pixel is used to extract a fovea-containing subimage on which thresholding and feature extraction techniques are applied so as to find fovea center. The methodology was evaluated on 1200 fundus images from the publicly available MESSIDOR database, 660 of which present signs of diabetic retinopathy. In 93.92% of these images, the distance between the methodology provided and actual fovea center position remained below 1/4 of one standard optic disc radius (i.e., 17, 26, and 27 pixels for MESSIDOR retinas of 910, 1380 and 1455 pixels in size, respectively).These results demanded very short computational time. Its effectiveness and robustness, together with its fast implementation, make this proposed automated fovea location method a suitable tool to be integrated into a complete prescreening system for early DR detection.

A fully automated, fast method to detect the fovea and the optic disc in digital colour photographs of the retina was presented by MeindertNiemeijer, Michael D. Abrmoff, Bram van Ginneken[29]. A kNN regressor is utilized to predict the distance in pixels in the image to the object of interest at any given location in the image based on a set of features measured at that location. The method combines cues measured directly in the image with cues derived from a segmentation of the retinal vasculature. An extensive evaluation was done on 500 images from a diabetic retinopathy screening program and 100 specially selected images containing gross abnormalities. The method found the optic disc in 99.4% and the fovea in 96.8% of regular screening images and for the images with abnormalities these numbers were 93.0% and 89.0% respectively.

In the paper presented by Sara Omid, Jamshid Shanbehzadeh, Zeinab Ghassabi, S. Shervin Ostadzadeh [30] Optic Disc detection is done by means of region growing. Image thresholding based on the entropy of the input image histogram and binary morphological operations are employed to find seed points in the region growing segmentation approach. The proposed algorithm uses an average filter to smooth input images and then, region growing is applied on the smoothed image to obtain a circular OD boundary. The proposed method has an average sensitivity/specificity of 98.6%/97.2% and it is computationally efficient in the presence of high-resolution images.

II. CONCLUSION

The segmentation of specific regions of the human retina has been an area of meticulous research in recent years. The localization, segmentation and optimization of two prominent retinal parts, namely, the optic disc and the fovea, accomplished in concurrence with high degrees of accuracy and precision forms the groundwork for developing several automated computer-aided systems for screening and diagnosis of ophthalmologic diseases. Various promising techniques and algorithms in medical image processing, relating to widely prevalent eye disorders such as glaucoma, diabetic retinopathy and age related macular degeneration, are predicated on novel findings in this field.Nevertheless, there is still vast scope for refinement and enhancement in the proposed segmentation methodologies.Formulation of robust and efficacious segmentation procedures in the keystone for real-time implementation of fast and precise diagnostic systems. It is expected that these strategies will, in all surety, drastically slice down the enormity of the sheer volume of medical images required to be handled by the concerned ophthalmologic experts.This review paper performs an appraisal of current methods for optic disc and fovea segmentation. We have retrospect early as well as contemporary literature based on the subject. Our prime intent was to acquaint reader with the existing segmentation techniques, impart an overview of the allied research in the domain and to present the array of employed algorithms found in literature. Apart from the above mentioned papers, 22 other papers were also analysed. A consolidated tabular representation of these papers is also provided here.

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