Automatic Optic Nerve Head Segmentation for Glaucomatous Detection using Hough Transform and Pyramidal Decomposition

M. Caroline Viola Stella Mary
Prof. & Head, Department of IT,
Francis Xavier Engineering College,
Tirunelveli – 627003

B. Jainudhin Sudar Marri,
Assistant Professor, Department of IT
SCAD College of Engineering & Technology,
Cheranmahadevi

ABSTRACT
The rapid development of digital imaging & computer vision has made an increase in potential to use the image processing technologies in ophthalmology. Image processing systems has become now a standard clinical practice with the development of medical diagnostic systems. The retinal images provide vital information about the health of the sensory part of the visual system. Retinal diseases like Glaucoma, Diabetic retinopathy, Age-related macular degeneration, Stargart's disease, retinopathy of prematurity that can lead to blindness manifest as artifacts in the retinal image. The retinal images usually suffer from non-uniform illumination. For a reliable diagnosis of the disease we need a good quality image. We are using two approaches for localization 1) Hough Space, 2) dividing the region into n x n regions. For the segmentation of the ONH we are using Pyramidal decomposition method.

Keywords
Glaucoma, Age-related macular degeneration, Stargart's disease, Diabetic Retinopathy, Fundus Image

1. INTRODUCTION
Medical image segmentation labels each voxel in the image indicating the tissue type and information about the anatomical structures. Inconsistent image quality, intensity inhomogneity, blurred edges, poorly defined boundaries are some of the difficulties in medical image segmentation. The advancement of medical imaging and computer vision technologies made a rapid change in image guided diagnostics. This provides the ophthalmologists with digitized data that gets used for the detection of retinal diseases based on image processing and pattern recognition technologies.

Ophthalmoscope is an instrument employed by clinicians to diagnose retinal diseases. Electronic media transmission advancement increases the usage of image processing in tele-opthalmology [18] for clinical decision makings in rural areas. Treatment of retinal diseases are available; the challenge lies in finding a cost effective approach with high sensitivity & specificity that can be applied to large populations in a timely manner to identify those who are at risk in the early stages of the disease. The progress of the disease is very often quiet in the early stages. The number of people affected has been increasing and patients are seldom aware of the disease, which can cause delay in treatment.

The retina, a layered tissue lining the interior of the eye converts the incoming light signal into a neural signal suitable for processing the signal by the brain. Rods and cones in the retina provide sensation of vision to the human eye, which includes color differentiation and perception of depth. Retina consists of one million nerve fibers, which groups together to form the optic nerve. The optic nerve exists out of the eye at the optic disc which is called the blind spot due to the lack of photoreceptors.The optic disc region is called as the Optic Nerve Head (ONH) which is circular in shape with a brighter appearance. The optic nerves leaving the eye form a natural cup shape deeper region and a sloping region called as the nueroretinal rim. The structure and information of the optic disc (OD) shows the severity of the diseases such as glaucoma.

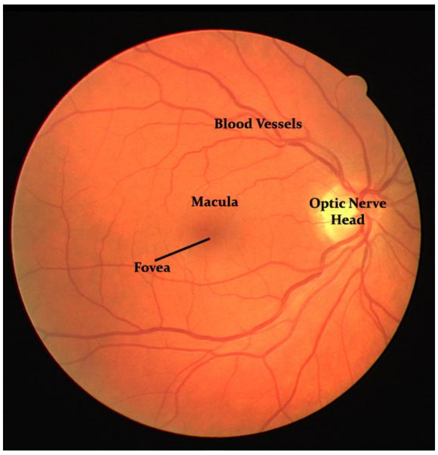


Fig.1. Fundus Image showing main Retinal Features

2. AUTOMATED DETECTION OF GLAUCOMA
Glaucoma is a chronic disease that affects the optic nerve, leading to losses in the visual field and eventual blindness[8]. Glaucoma is the second leading cause of blindness in the world next to cataract. Various risk factors related to glaucoma have been identified. It causes loss of retinal ganglion cells in a particular pattern. It is a type of optic neuropathy. A significant risk factor associated with glaucoma is raised intraocular pressure. The nerve damage in one person may be due to low pressure, while in another may be due to high eye pressure for years and may never develop damage. If glaucoma is left untreated it may lead to permanent damage of the optic nerve and cause blindness.

Rather than being considered as a single disease, glaucoma should be treated as a group of conditions originated from different causes. All these conditions resulted in an increased pressure inside the eye that destroyed the blood vessels and optic nerves leading to vision loss. This progressive and irreversible damage to the optic nerve often results with subtle

Fig.2. (a) Glaucoma affected image – Shows a deformity in the ONH size

signs or even without symptoms; thus it is nicknamed the "Sneak Thief of Sight" because the loss of vision normally occurs gradually over a long period of time and is often only recognized when the disease is quite advanced.

The vision loss due to the damage can never be restored back. Often, if defects were to be detected, they would be too late as significant damage to the nerve fibers may have occurred, causing a certain level of visual field loss. Therefore, as there is no cure for glaucoma, early detection of glaucoma is important because it can minimize damage and vision loss and allow for prompt and adequate treatments. Glaucoma affects one in two hundred people aged fifty and younger, and one in ten over the age of eighty. For every one in two hundred people aged fifty and less and also for every one in ten over the age of eighty, gets affected by glaucoma. It is possible to slow the progression of the disease if the condition is detected early enough and given medical treatment.

One of the important tests for diagnosing glaucoma is the determination and evaluation of the optic nerve head (ONH) from retinal images. The ONH is a circular area where the optic nerve fibers converge. As glaucoma progresses, it causes the nerve fibers to atrophy and results in apparent changes in the shape of the ONH. Often, variability in the appearance of the ONH caused by image contrast and obscurity by blood vessels leads to subjective manual screening and analysis.

3. LITERATURE SURVEY

Kenneth et al [1] used digital red-free fundus photographs for the automatic optic nerve detection and macula localization. The optic disc region is found by matching the parameters of the input image with the parameters in the database. The radius of the optic disc is found based on some empirical geomentric relationships between the vascular structure & optic nerve location and the initial contour is made. Lalonde et al [2] used a Haurdroff-based template matching technique on edge map guided by a pyramidal decomposition for large scale object tracking.

Sekhar et al [3] used morphological operations and Hough transform for localizing the optic disc. Jeyadevappa et al [7] has introduced a new speed term in the evolution step of variational level set for speeding up the convergence process. In images with intensity in homogeneity and noises, the variational level set tends to be slower and prone to leakage of contour outside the object boundary. Grau et al [8] presented a novel segmentation algorithm based on Expectation-maximization (EM), which incorporates an Anisotropic Markov Random Field (MRF) to introduce prior knowledge about the geometry of the structure.

Wells et al [9] used EM Algorithm to accurately segment the tissue types in MRI data. Juan et al [10] has implemented a deformable model technique for the detection of disc margin. Inoue et al [11] used discriminatory analysis for deciding a suitable threshold to extract the optic disc & optic cup. Liu et al [12] has proposed a variational level set method to automatically extract the disc. Methods using intensity and threshold level set are used for evaluating the cup boundary. Herzog et al [14] used a hybrid edge-supported boundary detector for the initial contour & then a model-based technique to identify the optic cup. Eswaran et al [15] applied the watershed transformation after the preprocessing steps of average filtering and contrast adjustments. Green channel of the RGB color space was used in localizing the optic disc. Yang et al [16] extracted the optic disc using multi-scale region & boundary hybrid snake method. Otsu thresholding was used to separate bright objects & dark background.

Hussain [17] segmented the Optic Nerve Head(ONH) using Active Contours(snakes) for location and its detection in terms of contours and energy formulation. Patton et al [18] identified patterns in data using Principal Component Analysis. ONH center was found by calculating the minimum distance between the original image & its projection. Graul et al [19] used Expectations-Maximizations (EM) Algorithm was used for segmenting beam-like structures. Then Anisotropic Markov Random Field was incorporated for coherence determination.

Boyer et al [21] used autonomous algorithms based on a parabolic model of cup geometry & an extension of the Markov model to segment the optic cup & disc. James Lowell et al [22] has proposed an algorithm for localization and segmentation of the optic nerve head boundary. A specialized correlation filter is used by the localization algorithm to match the key elements of the Optic Disc structure. Huiqi Li et al [23] used a modified active shape model(ASM) for detecting the disc boundary.Specialized Template matching method is used in localization & deformable contour model for segmentation.

4. LOCALIZATION OF ONH

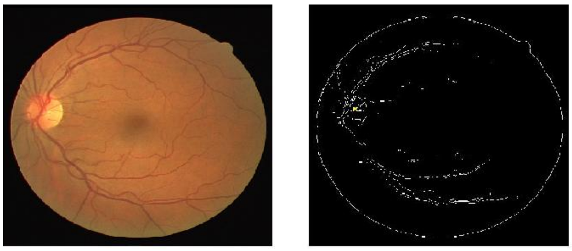
In retinal image analysis, the location of optic disc is very important and its location may lead to registering changes in the optic disc due to the progression of the disease. Hence initial localization methods can help in accurate segmentation of the optic disc. Li et al in 2001 [4] used the (PCA) in which the eigen vectors for a set of trained images is taken and the new retinal image is projected to the space specified by the eigen vectors. The minimum distance between the retinal image and and its projection locates the center of the optic disc. Principal Component Analysis (PCA) provides a sketch in reducing a complex data set to that of a lower dimension to reveal hidden, simplified structured data at times that lies beneath. Vidhya Sagar et al in 2003 [25] suggested that candidate regions are selected by taking the highest 5% intensity level pixels and hue value in the yellow range. The nearby pixels are then clustered. The clusters which are below a certain threshold value are discarded.

Sekhar et al in 2008 [3] analyzed the shapes of images through mathematical morphological processing. Toshiaki et al in 2007 defined that the high intensity pixel values are present in all three channels of R, G and B components of the ONH region. A P-tile thresholding is used to extract the ONH region but the blood vessels present in the ONH interferes in the extraction process. Sun Kwon et al in 2007 [13] stated that median filtering was applied to eliminate speckle noises without blurring of the image. Contrast of the image was enhanced by Contrast Limited Adaptive Histogram Equalization (CLAHE).

It is found that the green channel of the retinal image provides good contrast between the background and brightest anatomical components. Hence we adapted a contrast stretching transformation to make the features more visible. In our method we have utilized a circular hough transform for finding shapes in an image, and in this case the ONH's circular contour (See fig. 3). Similar to the linear hough transform, the Circular Hough transform uses the parametric form for a circle:

$$(x – a)2 + (y – b)2 = r2 \qquad (1)$$

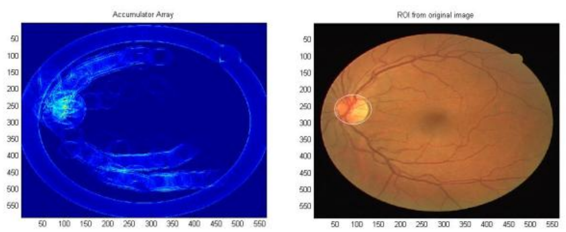
where (a, b) is the center of the circle of radius r that passes through (x, y). It has a hough space with three sets of parameters, the accumulator, its center and its radius. The peaks of the contributory circle in the accumulator space overlap at the center. The circle whose radius is nearest to the optic disc radius is taken and an initial contour is drawn.



(a) (b)

Fig.3. (a) Fundus Image with edge detected, (b) Edge detected and hough transform has marked the center of ONH in Yellow dot

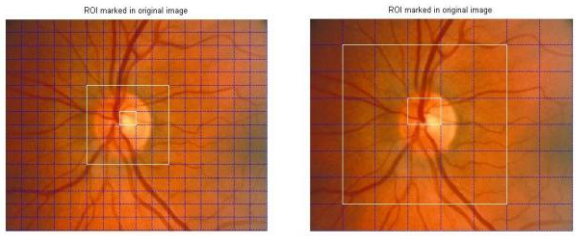
Morphological operations are done to delineate the edges and reduce the error. A thinning effect is done to improve the accuracy of detection. A sample of 100 images were taken from the DRIVE, DIARET0 databases for the removal of ROI from the fundus image for ONH detection.



(b) (b)

Fig.4. (a) Accumulator Array – hough circles, (b) ONH detected in the original image using hough transform

We adapted another method suggested by Liu at al [12] in which the pixels with 0.5% highest intensity are automatically selected by dividing the image into 64 regions (See fig 5). The region with the maximum number of high intensity pixels can be taken as the region with ONH center. A rectangle with twice the diameter is taken as Region of Interest. We tried by



(a) (b)

Fig.5. (a) 16 x 16 split – 256 regions, (b) 8 x 8 – 64 regions

For taking the ROI of the ONH from the fundus image using 8 x 8 regions as well as 16 x 16 regions. Division of the image into 8 x 8 regions had a better effect in getting the ONH Region of Interest.

5. AUTOMATIC SEGMENTATION OF ONH

Balasubramanian et al in 2009 [20] suggested that structural glaucomatous damages are not drastic in the early stages. Hence to detect the progressive glaucomatous changes in the eye, the topographies of the ONH are compared with the baseline topography of the eye. He had used Statistical Imaging Mapping (SIM) of the Retina for estimating the pixel level changes.

Chrastek et al [24] estimated that the optic nerve head can be found by identifying the dark areas in the image. A mean gray value and a standard deviation of all pixels is used to determine the threshold θONH. A Euclidian Distance Map (EDM) assigns each pixel the distance to the next boundary. The search space was restricted to a radius of 100 pixels. To detect the margin of the optic disc, a hough transform is used whose radius starts with a large value and gets successively reduced. Using internal and external forces of the modified active contour model called snakes, a final contour is drawn.

Ozareh et al [5], [6] used mathematical morphology to extract important shape characteristics and relevant information. Tobin et al in 2007 [1] had used a prior probability with other statistical data from training for the localization of the ON. The Probabilistic features are a density map of the vessels, an average thickness map, an average orientation map, and a luminance map. The prior probabilities are combined with the conditional densities for the calculation of posterior probabilities using the Bayes' rule, which are used to develop a likelihood estimate for the location of the ON.

After localizing the ONH we used the Snake approaches for drawing the initial contour. The images were pre-processed in three stages: 1) image equalization to enhance the difference between the bright nerve head and the darker surrounding retinal region 2) image thresholding to remove pixels that are definitely not part of the nerve head and 3) image enhancing (edge detailing) using a pyramid edge detector. The algorithm failed to detect the boundary of the ONH in poorly exposed images, since the sensitivity of the snake algorithm to the pre-processed image was small.

A pyramidal decomposition method suggested by Lalonde et al [2] was used to determine the potential regions which might contain the optic disc. We preferably used the green channel

(G) in the original RGB image and also checked with the Intensity (I) channel in the HSI image, as they have the optic disc in a clearer form. For efficient implementation a Haar-based discrete wavelet transform is used in creating the pyramid. We have used here a four- and five-level decomposition of the image in the data set is done and the resolution levels are adequate as only a few bright pixels fall into the original OD region. The pixels that are having high intensity values than the mean pixel value are considered to be candidate regions. Smoothing is done inside each of the candidate region and the brightest pixel is selected as a possible OD center point.

CVR, a simple confidence value, to assess the relevance of each hypothesis, is defined as the ratio between the average pixel intensity inside a circular region centered on the brightest pixel of radius, which is approximately equal to the expected radius of the optic disc in the image and the average intensity in its neighborhood. It captures a circular patch of bright pixels surrounded by darker pixels. A rectangle slightly larger than the bounding box around the circular region is taken as the neighborhood. Potential OD regions, along with their confidence values CVR and high-intensity pixel

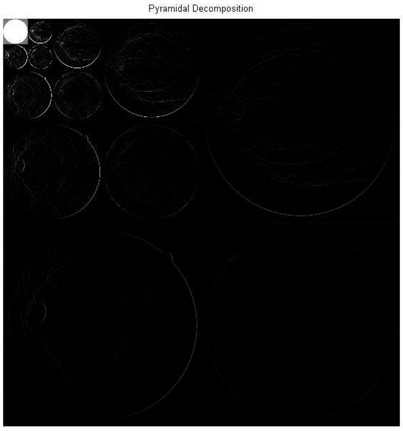


Fig.6. Pyramidal Decomposition

coordinates representing its center is got as the intermediate result and for further analysis, the top ten candidates are retained.

To locate the potential OD contours we used an algorithm based on Hausdorff distance. The candidate regions 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. Contiguous regions are aggregated into a single zone in order to limit the number of ROIs in the image. One or two search zones may result from this aggregation for a retinal image of good quality. Binary image is given as inputs to Hausdorff based matching technique. For each aggregated region, perform edge detection and do thresholding. Rayleigh probabilistic modeling method is being used for detecting the noisy edge distribution. A proper threshold has to be selected as it requires choosing a probability of misinterpreting a noisy edge as a true edge. The estimation of T is done in the edge map using noisy edges only. The procedure adopted is as follows: Canny edge detection is done using Canny hysteresis in the region of interest to capture as many edges as possible. The high threshold is reassigned to a value that captures 10% of all edges in the step 1 capturing the strong edges only. The second edge map is subtracted from the first one to get the noisy edge map IN. M edge pixels are extracted within a small window in the center of the noisy edge map IN to compute T. The final thresholded binary edge map IT is obtained using the threshold T and is being used for calculating the Hausdorff-based template matching.

The Hausdorff distance H(A,B) is defined to provide a degree of mismatch between two sets of points A and B by measuring the distance of the point of A that is farthest from any point of B and vice versa. In a binary image IT, A represents the set of black pixels and B the set of pixels that form a black circular template. The Hausdorff distance is calculated between the template and the underlying arrangement of pixels in IT. If the match is exact, then the distance is zero which increases as the resemblance weakens. This even helps in certainly locating the OD in the absence of precise disc borders and presence of vessels coming out of the disc. Two confidence values CVH and CVR are assigned to each Hausdorff candidates. CVH, is the proportion of template pixels overlapping edge pixels in the thresholded

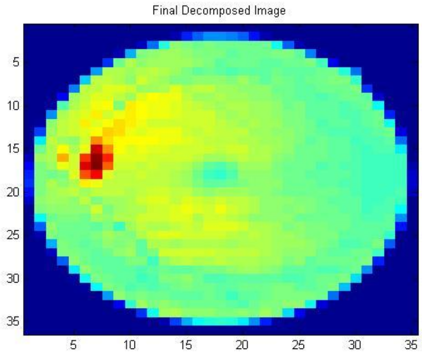


Fig.7. Final Decomposed Image

edge map IT. CVR, is the ratio between the average pixel intensity over the template candidate and the average intensity over its neighborhood. This indicates how well the candidate is aligned with the OD from a pixel-intensity point of view and higher CVR indicates better aligned candidates. The most likely OD position and radius are found by determining the candidate with the highest overall (global) confidence.

6. CONCLUSION

The results of the optic disc segmentation via pyramidal decomposition are able to give 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. Hence if multiple initializations are being used then we will have a better performance.

To conclude we have proposed a model approach using discriminant analysis. Our method has shown an improvement over the rest. Finally we are examining applications of our method for making actual measurements and classifications through automated methods. In our proposed work, we have planned to calculate parameters which may determine the progression level towards glaucoma.

7. REFERENCES

[1] Kenneth W. Tobin, Senior Edward Chaum, V. Priya Govindasamy, and Thomas P. Karnowski, "Detection Of Anatomic Structures In Human Retinal Imagery" in IEEE Transactions On Medical Imaging, Vol. 26, No. 12, December 2007, Page 1732

[2] Marc Lalonde, Mario Beaulieu, and Langis Gagnon, "Fast And Robust Optic Disc Detection Using Pyramidal Decomposition And Hausdorff-Based Template" in IEEE Transactions On Medical Imaging, Vol 20, No 11, November 2001

[3] S.Sekhar, W.Al-Nuaimy and A.K.Nandi, "Automated Localization of Optic Disk and Fovea in Retinal Fundus Images" in EUSIPCO Proceedings (European Association for Signal Processing), 16th European Signal Processing Conference (EUSIPCO 2008), Lausanne, Switzerland, August 25-29, 2008, copyright by EURASIP

[4] Huiqi Li, Opas Chutatapec, "Automatic Location Of Optic Disk In Retinal Images", in Proceedings. 2001 International Conference on Image Processing, October 2001, Pages 837 – 840 vol.2, Thessaloniki, Greece

[5] Alireza Osareh, Majid Mirmehdi , Barry Thomas and Richard Markhamb, "Colour Morphology And Snakes For Optic Disc Localization", in the 6th Medical Image Understanding and Analysis Conference. A Houston, R Zwiggelaar, (eds.), pp. 21–24. July 2002

[6] Alireza Osareh, Majid Mirmehdi, Barry Thomas and Richard Markham, "Comparison Of Colour Spaces For Optic Disc Localization In Retinal Images", in the 16th International Conference on Pattern Recognition (ICPR'02), August 2002, IEEE Computer Society.

[7] D.Jayadevappa, S.Srinivas Kumar, and D.S.Murty, "A New Deformable Model Based On Level Sets for Medical Image Segmentation", in the IAENG International Journal of Computer Science, 36:3, IJCS_36_3_01

[8] Vicente Grau, J. Crawford Downs, and Claude F. Burgoyne, "Segmentation Of Trabeculated Structures Using An Anisotropic Markov Random Field: Application To The Study Of The Optic Nerve Head In Glaucoma", IEEE Transactions on Medical Imaging, Vol. 25, No. 3, March 2006. Pg: 245

[9] W. M. Wells, W. E. L. Grimson, R. Kikinis, and F. A. Jolesz, "Adaptive Segmentation Of MRI Data", IEEE Transactions on Medical Imaging, Vol. 15, NO. 4, August 1996. Pg: 429

[10] Juan Xu,Hiroshi Ishikawa,Gadi Wollstein,Richard A. Bilonick,Kyung R. Sung,Larry Kagemann,Kelly A. Townsend,and Joel S. Schuman, "Automated Assessment Of The Optic Nerve Head On Stereo Disc Photographs", in the Invest. Ophthalmol. Vis. Sci. June 2008 vol. 49 no. 6 2512-2517

[11] Inoue, Kenji Yanashima, Kazushige Magatani, Takuro Kurihara, Naoto, "Development Of A Simple Diagnostic Method For The Glaucoma Using Ocular Fundus Pictures", in the Proceedings of the 2005 IEEE Engineering in Medicine and Biology 27th Annual Conference Shanghai, China, September 1-4, 2005

[12] J. Liu, D. W. K. Wong, J.H. Lim, X. Jia, F. Yin, H. Li, W. Xiong, T. Y. Wong, "Optic Cup and Disk Extraction From Retinal Fundus Images For Determination Of Cup-To-Disc Ratio", in the Singapore IEEE Conference on Industrial Electronics and Applications

[13] Michael D. Abra`moff, Wallace L. M. Alward, Emily C. Greenlee, Lesya Shuba,Chan Y. Kim,John H. Fingert, and Young H. Kwon, "Automated Segmentation Of The Optic Disc From Stereo Color Photographs Using Physiologically Plausible Features"

[14] Artemas Herzog, Kim L. Boyer, Cynthia Roberts, "Extracting The Optic Disk Endpoints In Optical Coherence Tomography Data", in the Proceedings of Seventh IEEE workshop on Applications of Computer Vision, 2005

[15] C. Eswaran, Ahmed Wasif Reza, and Subhas Hati,"Extraction Of The Contours Of Optic Disc And Exudates Based On Marker-Controlled Watershed Segmentation", in the Malaysia International Conference on Computer Science and Information Technology 2008

[16] Xiaoyun Yang, Philip Morrow, Bryan Scotney, "Optic Nerve Head Segmentation In HRT Images", School of Computing and Information, Engineering, University of Ulster.

[17] Abdul Razak Hussain, "Optic Nerve Head Segmentation Using Genetic Active Contours", in the International Conference on Computer and Communication Engineering 2008 May 13-15, 2008 Kuala Lumpur, Malaysia

[18] Niall Patton,Tariq M. Aslam,Thomas MacGillivray,Ian J. Deary,Baljean Dhillon,Robert H. Eikelboom, Kanagasingam Yogesan, Ian J. Constable, "Retinal Image Analysis: Concepts, Applications And Potential".

[19] V. Grau1, J.C. Downs1, C.F. Burgoyne, "Segmentation Of Connective Tissue In The Optic Nerve Head Using An Anisotropic Markov Random Field", LSU Eye Center, LSU Health Sciences Center, New Orleans, Louisiana, USA.

[20] Madhusudhanan Balasubramanian, Stanislav Zabi´c, Christopher Bowd, Hilary W. Thompson, Peter Wolenski, S. Sitharama Iyengar, Bijaya B. Karki, and Linda M. Zangwill, "A Framework For Detecting Glaucomatous Progression In The Optic Nerve Head Of An Eye Using Proper Orthogonal Decomposition".

[21] Kim L. Boyer, Artemas Herzog, and Cynthia Roberts, "Automatic Recovery Of The Optic Nerve Head Geometry In Optical Coherence Tomography", IEEE Transactions On Medical Imaging, Vol. 25, No. 5, May 2006. Pg No:553

[22] David Steel, Ansu Basu, Robert Ryder, Eric Fletcher, and Lee Kennedy, James Lowell, Andrew Hunter, "Optic Nerve Head Segmentation", in the IEEE Transactions on Medical Imaging, Vol. 23, No. 2, February 2004. Pg: 256

[23] Huiqi Li, Member, IEEE, and Opas Chutatape, "Automated Feature Extraction In Color Retinal Images By A Model Based Approach", in the IEEE Transactions on Biomedical Engineering, Vol. 51, NO. 2, February 2004. Pg: 246

[24] Radim Chrastek, Mathias Wolf, Klaus Donath, Heinrich Neumann, "Automated Segmentation Of The Optic Nerve Head For Glaucoma Diagonosis", at the FORWISS Knowledge Research Group, Erlangen.

[25] Anantha Vidya Sagar, S Balasubramanian, V.Chandrasekaran, "Automatic Detection Of Anatomical Structures In Digital Fundus Retinal Images", in the MVA2007 IAPR Conference on Machine Vision Applications, May 16-18, 2007, Tokyo, JAPAN

[26] Seng Soon Leel , Mandava Rajeswari, Dhanesh Ramachandram, "Preliminary And Multi Features Localization Of Optic Disc In Colour Fundus Images", in the Malaysia National Computer Science Postgraduate Colloquium 2005 (NaCSPC'05)