2014 Fifth International Conference on Intelligent Systems, Modelling and Simulation

eOpthalmologist –Intelligent Eye Disease Diagnosis System

Manoujitha Kugamourthy
Department of Computing
Informatics Institute of technology in affiliation with
University of Westminster
Colombo 06, Sri Lanka
kmanoujitha@gmail.com

Oshini Goonetileke
Department of Computing
Informatics Institute of technology in affiliation with
University of Westminster
Colombo 06, Sri Lanka
Oshini.g@iit.ac.lk

Abstract—**The human eye is a vital organ of vision which can be affected by many diseases. One of the most common diseases that have affected people of over 50 years of age is Age Related Macular Degeneration. Patients in their fifties or more or who have undergone surgery for cataract and glaucoma should have their eyes examined annually. Inspection provides a large number of Fundus images and medical professionals has to continually peruse them spending valuable time and energy. Current methods of detection and assessment are manual, expensive and potentially inconsistent. Thus, it would be more cost effective and beneficial if the initial task of analysing retinal photographs is automated. The proposed solution would act as an early warning system, where an ophthalmologist will be able to analyse numerous images within a brief period and spend more time on those patients who are actually in desideratum of their expertise**

KeyWords: Computer Vision, Fundus image, drusens, Image processing

I. INTRODUCTION

Eye is a vital organ of vision, which gives us the sense of sight, allowing us to learn more about the surrounding world than we do with any other four senses, There are many diseases which have an impact on the human vision. One of the most common diseases that affect people over 50 years of age is Age Related Macular Degeneration (ARMD), which is associated with aging that gradually destroys the eye's central vision which is needed for seeing objects clearly and for common daily tasks. As this disease is asymptomatic at its initial stage, the patient is not aware of its presence.

ARMD occurs in 2 forms: wet and dry. Dry ARMD occurs when light- sensitive cells in the macula slowly break down, gradually blurring central vision in the affected eye. Wet ARMD occurs when abnormal blood vessels behind the retina start to grow under the macula [1]. The dry/atrophic type affects approximately 85-90% of individuals with ARMD. Its cause is unknown, it tends to progress more slowly than the wet type, and there is not as of yet an approved treatment or cure. The wet/neovascular type affects approximately 10-15% of individuals with ARMD, but accounts for approximately 90% of all cases of severe vision loss from the disease.

Since 2000, the number of people who are in their fifties and older with ARMD has climbed by 25% around the world. World Health organisation has ranked ARMD third among the global causes of visual impairment with a blindness prevalence of 8.7%.It also says as the population 50 years of age and older has increased by nearly 30% and this increase in the population increases the number of people affected by potentially blinding eye conditions such as ARMD, diabetic retinopathy and glaucoma. (WHO, 2012)

Patients who are in their fifties or more or who have gone through a surgery for cataract and glaucoma should have their eyes checked by an ophthalmologist annually to see if macular degeneration is present or progressing. This provides a huge number of fundus images, which is a creation of a photograph of the interior surface of the eye.
Hence medical professionals have to spend much time and energy to review these fundus images. Current methods of detection and assessment of ARMD is manual, expensive and potentially inconsistent and require highly trained personnel to facilitate the process. The high cost of examination and the shortage of ophthalmologists, especially in rural areas, are the prominent factors that hamper patients from obtaining regular examinations.
Thus, it would be more cost effective and helpful if the initial task of analyzing the retinal photographs can be automated. In this way, individuals who are diagnosed by the automatic computer system as having early retinal lesions, which are the abnormality in the retina would be referred to an ophthalmologist for further evaluation. This would sanction more patients to be screened per year and the ophthalmologists to spend more time on those patients who are actually in desideratum of their expertise.

In this paper, we propose a method to automatically detect the macula area and find the drusens in retinal fundus images. The approach is fully described in the next section. In Section III, we present the results of our experiments on a dataset of some images and conclude the findings in Section IV.

II. METHOD

The initial step is acquisition of images which needs to be pre-processed and determine the optic disk. Identifying the optic disc will help finding the macular area approximately using Region of Interest. Then that region is used in identifying the drusens which is the most important symptom with Thresholding and edge detection. The

2166-0662/14 $31.00 © 2014 IEEE
DOI 10.1109/ISMS.2014.64

severity of the disease is calculated with the count of the pixels within the detected drusens.

A. Image Acquisition

The initial step of the method is image acquisition. Retinal images are acquired by a specialized camera called fundus camera. Mydriatic and non-mydriatic fundus cameras are used for retinal photograph.Those fundus images are one type of images which are used in ophthalmology. These images are found in jpg/jpeg image format for further processing. Fluorescein Angiography (FA) and optical coherence tomography (OCT) are also used for diagnosis of ARMD. Eventhough there are other imaging modalities in eye examinations like adaptive optics ophthalmoscopy, color Doppler imaging, computed tomography, confocal laser scanning microscope, magnetic resonance, ophthalmic ultrasound, retinal thickness analyzer and scanning laser polarimetry above mentioned fundus images, AF images and OCT are the widely used modalities in the diagnosis of ARMD. Figure1 illustrates fundus image , OCT and FA images.

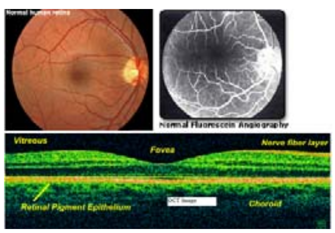


Figure 1- Image acquisition samples

B. Optic Disk Localization

OD is the brightest region in the color fundus images and also they have many distinctive properties in the fundus image that can be used in their detection. Identifying the optic disk will help finding other features using their geographical relationship. Here Thresholding is used to identify the brightest part of the image. There are many methods which can be used in the localization of optic disk. Kose.C [5] has used vertical Sobel algorithm to detect the OD and the intensity changes and edges around the optic disk are used to determine the vertical location of OD. Here, the filter makes the edges on the image more evident. The maximum values of histograms are used to determine the position of optic disk. The histogram of the vertical stripe around the optic disk is only considered to calculate horizontal position of the OD. If there is some degeneration around the optic disk, the result may be a misdetection. To reduce the misdetection rate, he has used an experimentally determined threshold value. Lalonde [7] uses canny edge detector and Ghafar [2] uses circular hough transform for detecting optic disk.

Youssif [13] detects OD by using vessel's direction matched filter. These methods are based on edge characteristics. Lowell et al [6] have proposed the template matching based OD detection technique. This technique is implemented on normal and abnormal images. Experimental results concluded that the proposed algorithm is suitable even for blurred images. Babu et al [1] have used using K-mean clustering algorithm in OD segmentation. The K-seeds for the K-means segmentation were automatically determined using hill-climbing algorithm. Active shape model (ASM) based optical disk detection is implemented by Huiqi et al[4]. The initialization of the parameters for this model is based on Principal Component Analysis technique. The faster convergence rate and the robustness of the technique are provedby experimental results. But this technique was tested only on few images.

Kavitha [9] have used ROI based segmentation to localize optic disk. Which is estimated by using contour method the optic cup was segmented using the component analysis and the threshold methods separately. This method has been proved to be more accurate one for segmentation. But the drawback is that the region is pre-selected.

With all the survey .threshold method has been o identified as the appropriate method to detect the optic disk. Segmentation algorithms using thresholds are based on one of two basic properties of intensity values discontinuity and similarity. First category is to partition an image based on abrupt changes in intensity, such as edges in an image. Second category is based on partitioning an image into regions that are similar according to predefined criteria [5]. In the fundus image segmenting the optic disk and the drusens from the other parts of the retina can be done using thresholding as the intensity of optic disk and the drusens will highly vary. The simplest approach to segment an image is using thresholding. Threshold is one of the widely used methods for image segmentation. It is useful in discriminating foreground from the background.

A minimum and a maximum of RGB values are given as the threshold value and the regions which are in between that region can be identified. This technique can be expressed as,

$$T=T[x, y, p(x, y), f(x, y] \quad - \quad (1)$$

Where: T is the threshold value. x, y are the coordinates of the threshold value point. p (x,y) ,f(x,y) are points the grey level image pixels. Threshold image g(x,y) can be defined as :

$$(g,x) = \begin{cases} 1 \ if \ f(x,y) > T \\ 0 \ if \ f(x,y) < T \end{cases} \quad - \quad (2)$$

By selecting an adequate threshold value T, the grey level image can be converted to binary image. The binary image should contain all of the essential information about the position and shape of the objects of interest (foreground). The advantage of obtaining first a binary image is that it reduces the complexity of the data and simplifies the process of recognition and classification. Optic Disk is located with this Thresholding. Thresholding also removes the unwanted parts like blood vessels and locates only the optic disk and also the bright drusens when available. But by finding out the macular region the drusens can be detected. Next section discussed about the region selection.

C. Macular Region Detection

The next step is finding the Region which contains the macula area. According to Kose[5] macula can easily be located by detecting the optic disk if images are taken at certain scale, angle and position. The relative locations of optic disk and macula and the distance between these invariants can be used to locate the macula. If retinal fundus images are taken from a certain position, the macula in left and right eyes can be located on right or left side of the image easily. Hence, location of the macula is determined by considering the location of optic disk, and the relative distance between optic disk and macula. Therefore, firstly, whether the location of macula is on the right or left side of the image is determined, and then experimental information such as relative positions and distances is used to locate the macula more precisely. If the optic disk is close to the left side of image, the macula is on the right. Otherwise, the macula is on the left. Sekhar et al [10] have also used the geometric relations between the OD and macula to detect the central region of macula which is called as fovea.
Locating the macula based on the geographical relationship with the optic disk is used in this research. ROI is set relatively to the points from optic disk and macula area is covered.

D. Drusen Detection

There are some characteristics of retinal image that make segmentation more difficult, e.g., low contrast, indistinct boundaries of drusen, and non-uniform background.

Grey level thresholding is the simplest exudate segmentation method [9]. However, the automatic selection of a threshold is difficult due to the uneven illumination of the HEs. A global threshold is set manually for each image in, whereas a local threshold is used in for different regions.

Goldbaum et al [3] has made a research on "automated diagnosis and retinal image understanding." Features like compactness, object colour, border colour, texture measures, edge gradient, area and turns per length of the border were used to segment bright lesions. This method detected bright objects with an accuracy of 89%.
There are some major challenges in dark lesion detection, which are addressed below

- Segmentation of small micro aneurysms in the areas of low image contrast

- The presence of bright pathologies.

Normally bright lesions have sharp edges. When these bright lesions are close to each other small islands of normal retina are created between them. They may be picked up as false positives. To solve these problems, a hybrid dark lesion detection method is proposed by an anonymous author. This method combines morphological based dark lesion detection and candidate dark lesion detection scheme based on matched filtering and local relative entropy. The same author has proposed another new method to detect bright lesions based on Spatially Weighted Fuzzy C-Means (SWFCM).The weight in the SWFCM algorithm is inspired by KNN classifier that considers the influence of neighbourhood on the central pixel, is changed to improve the performance of clustering. Due to the consideration of the neighbourhood information, the proposed method is noise resistant. The gray level histogram of the fundus image is used in the proposed SWFCM clustering instead of the whole data of the image. Hence the computation time is very less for the proposed method compared to other FCM based methods discussed above.

Parvathi [12] proposed local energy computation to detect and count drusen. They used Gabor filters to compute local energy of the retinal image. To detect area of drusen, the filter parameters have been selected to capture the high frequency component (edges) of drusen in the image. Since the high frequency is presented in many parts of image such as blood vessels, so they need to be eliminated. To do this, dark pixels of vessels in the green channel were replaced with the local mean of their neighbours. However, there are two shortcomings with local energy based drusen detection: one, selection of the appropriate parameters and, two, obtaining a reliable drusen count. Furthermore, a drawback of this approach is requirement of many pre-processing steps prior to the segmentation stage.
In this research the drsen itself is identified in the previous step while identifying the optic disk, whereas both optic disk and drusens have the same brightness, but again drusen is distinguished from the optic disk from the geographical characteristics. The following image shows the detection of drusen.

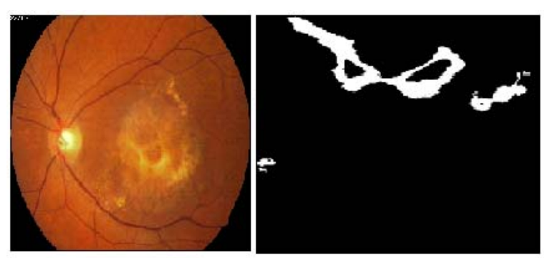


Figure 2-Normal image and threshold image

Once the macular area is detected the edges of the drusens or the normal healthy macular needs to be detected. Edge Detection has been used to identify the exact edges of the abnormalities. Edge detection refers to the process of identifying and locating sharp discontinuities in an image. Edge-detection. Canny operator has been used as the edge detection operator in this research. Even though canny edge detector is time consuming and false zero crossing the advantages are using probability for finding error rate, Localization and response, Improving signal to noise ratio, Better detection specially in noise conditions. Canny edge detection satisfies the following criteria which are identified as the criteria which need to be satisfied to consider the algorithm optimal,

- Good detection-the algorithm should mark as many real edges in the image as possible.

- Good localization-edges marked should be as close as possible to the edge in the real image.

- Minimal response-a given edge in the image should only be marked once, and where possible, image noise should not create false edges.

Therefore canny detector was chosen for edge detection. The Canny Edge Detector is one of the most commonly used image processing tools, detecting edges in a very robust manner. It is a multi-step process, which can be implemented on the GPU as a sequence of filters.

First step of edge detection is converting the image to greyscale image. Then the noise is removed from the grey-scaled image using Gaussian filter. The kernel of a Gaussian filter with a standard deviation of σ = 1.4 is shown in Equation (3).

$$B = \frac{1}{159}\begin{bmatrix} 2 & 4 & 5 & 4 & 2 \\ 4 & 9 & 12 & 9 & 4 \\ 5 & 12 & 15 & 12 & 5 \\ 4 & 9 & 12 & 9 & 4 \\ 2 & 4 & 5 & 4 & 2 \end{bmatrix} \quad - (3)$$

Then gradient magnitude and angle computation is the next step. The Canny algorithm basically finds edges where the grayscale intensity of the image changes the most. These areas are found by determining gradients of the image. Gradients at each pixel in the image smoothed using Gaussian filter are determined by applying what is known as the Sobel-operator First step is to approximate the gradient in the x- and y-direction respectively by applying the kernels shown in the following equation (4)

$$K_{GX} = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \qquad K_{GY} = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} \quad - (4)$$

The gradient magnitudes (also known as the edge strengths) can then be determined as an Euclidean distance measure by applying the law of Pythagoras as shown in Equation (5). It is sometimes simplified by applying Manhattan distance measure as shown in Equation (6) to reduce the computational complexity

$$|G| = \sqrt{G_x^2 + G_y^2} \quad - (5)$$

$$|G| = |G_x| + |G_y| \quad - (6)$$

Where, Gx and Gy are the gradients in the x- and y-directions respectively. Images of the gradient magnitudes often indicate the edges quite clearly. However, the edges are typically broad and thus do not indicate exactly where the edges are. To make it possible to determine this the direction of the edges must be determined and stored as shown in Equation (7),

$$\theta = \arctan\left(\frac{G_y}{G_x}\right) \quad - (7)$$

When using the Sobel filter, the edges it finds can be either very thick or very narrow depending on the intensity across the edge and how much the image was blurred first. One would like to have edges that are only one pixel wide. Maximum suppression keeps only those pixels on an edge with the highest gradient magnitude. These maximal magnitudes should occur right at the edge boundary, and the gradient magnitude should fall off with distance from the edge. So, three pixels in a 3×3 around pixel (x, y)are examined

- If θ′ (x, y) = 0 ◦, then the pixels (x+1,y),(x, y)and (x−1,y) are examined.

- If θ′(x, y) = 90◦, then the pixels(x, y+ 1),(x, y), and(x, y−1)are examined.

- If θ′ (x, y) = 45◦, then the pixels(x+1, y+ 1),(x, y),and(x−1,y−1)are examined.
- If θ′(x, y) = 135◦, then the pixels(x+1,y−1),(x, y), and(x−1, y+ 1)are examined.

If pixel (x, y) has the highest gradient magnitude of the three pixels examined, it is kept as an edge. If one of the other two pixels has a higher gradient magnitude, then pixel(x, y) is not on the "centre" of the edge and should not be classified as an edge pixel

Final step of edge detection is hysteresis Thresholding. Some of the edges detected in the previous will not be accurate there may be noise in that, so that noise should be eliminated. Eliminating pixels whose gradient magnitude D falls below some threshold removes the worst of this problem, but it introduces a new problem. A simple threshold may actually remove valid parts of a connected edge, leaving a disconnected final edge image. This happens in regions where the edge's gradient magnitude fluctuates between just above and just below the threshold. Hysteresis is one way of solving this problem. Instead of choosing a single threshold, two thresholds thigh and tlow are used. Pixels with a gradient magnitude D < t low are discarded immediately. However, pixels with t low ≤ D < t high are only kept if they form a continuous edge line with pixels with high gradient magnitude (i.e. above t high).

- If pixel (x, y) has gradient magnitude less than t_{low} discard the edge (write out black).
- If pixel(x,y) has gradient magnitude greater than t high keep the edge (write out white).
- If pixel (x, y) has gradient magnitude between tlow and t high and any of its neighbors in a 3×3 region around it have gradient magnitudes greater than thigh, keep the edge (write out white).
- If none of pixel (x,y)'s neighbours have high gradient magnitudes but atleast one falls between tlow and thigh, search the 5x5 region to see if any of these pixels have a magnitude greater than t high. If so keep the edge (write out white).
- Else discard the edge .(write out black)
- The following image shows the final output of detected edges,

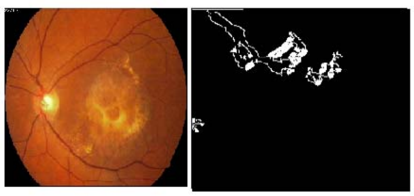


Figure 3-Final Edges

After the edges are finalised, to identify the severity of the disease the number of pixels within the edges are counted.

III. EXPERIMENTS AND RESULTS

To evaluate the proposed automatic method to diagnose ARMD, a dataset was collected from a eye test laboratory in Srilanka. This data set consists of 50 coloured fundus images composed of normal eyes and ARMD eyes with different severities captured by a customized camera that is mounted to a microscope with intricate lenses and mirrors

Each subsection discussed in section 2 was tested with those 50 images.

The results show that this approach has a high success rate in detecting the macular region and diagnose ARMD eyes. It was able to identify exacntly the macular area and detect the drusens properly and also finally detect the exact edges. The exact macular area was identified I both right and left eyes. Both positive and negative scenarios were also tested with this dataset.

Drusens segmentation is the most important part in ARMD detection. According to the knowledge of liver segmentation technologies which is gained from the technologies' analysis in literature review, out of suitable existing algorithm has been applied to 20 retinal abdomen image and the results have been examined to discover the most appropriate algorithm. The following strategy was used to find out the accuracy level of each algorithm.

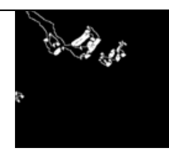
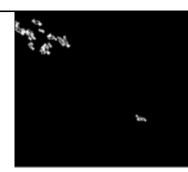
$$accuracy = \frac{total\ number\ of\ segmented\ images * 100}{total\ number\ of\ tested\ images}$$

50 images were chosen for testing purposes and 46 images were segmented and the drusens were detected accurately. So the accuracy is

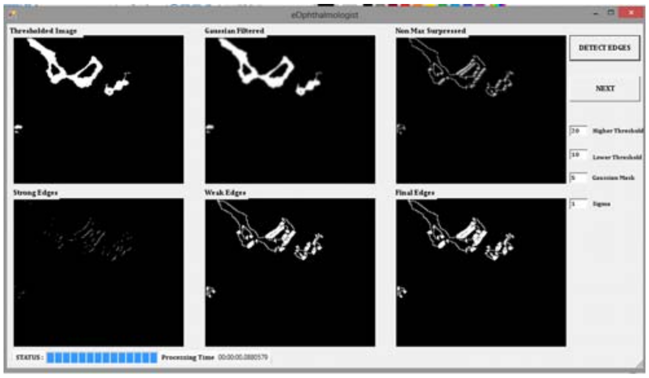
Accuracy = (46/50)*100% = 92 %

Performance testing is a testing approach that is taken up to determine how fast and efficiently the system would perform under a particular work load. The main challenge of this project is to ensure that accurate results are achieved through the chosen algorithm and the performance of the images' processing and segmenting can be measured and displayed. Further getting accurate results in detecting the drusen is also important when considering the performance. Therefore, a performance test was carried out in order to find how accurately the chosen algorithms will output results for a given response time. Performance of each subsection was also calculated with the computational time taken for each step.

Sample final output is given below in the image,

Input	Output	Disease Category
		ARMD- Severe
		ARMD- Mild
		Normal

Sample Output of each step is given in the following image, where it accurately detected the features and diagnosed ARMD eyes and also a sample computation time is also given,



IV. CONCLUSION AND RECOMMENDATIONS

A method for ARMD diagnosis is discussed in this paper. In the approach first the optic disk is detected using threshold and using thee geographical features macular area is detected and the drusens are found using the canny edge detector. The reasons for choosing these technologies are also discussed in the paper. Some existing methods were tried on a data set and accurate method was found for segmentation which is the most important feature.

Then using another data set the implemented features were experimented and 92% accuracy was obtained. The main features and important requirements identified were developed. But there are some limitations in this product which are listed down below,

- Image captured with the old generation fundus camera cannot be supported by the system due to the lack in quality.
- Only colour retinal fundus images can be supported by the system.
- One of the major drawbacks in this proposed system is that this system is not connected with the database and the data is maintained in files and folder system which is not considered to be and efficient way of handling the data.
- Though it was said that the performance was up to the standard what was expected , it has not reached up to 100% precision in segmentation, due to the differentiation of drusens and different images
- Another drawback in this system is that only one image can be uploaded at a time for analysis purposes.

The following are some recommendation where the product can be improved and more accuracy can be obtained in future.

- Since this proposed system is a Desktop Applications it is expected to press forward this system by constructing it a as web application.
- Adding artificial intelligence is also recommendation as it could increase the accuracy level.
- Here only fundus images are considered. Processing of auto-fluorescence image along with fundus image and also incorporating OCT report will give more accurate results.

REFERENCES

[1] Babu, T.R, 2011. Automatic Detection of Glaucoma Using Fundus Image. European Journal of Scientific Research, 59, 22Boeykens, S., Quintero, M. S. & Neuckermans, H. 2008. Improving Architectural Design Analysis using 3D Modeling and Visualization Techniques.

[2] Ghafar, R. A. A, Morris, T, Ritchings, . T. and Wood,I"Detection and characterisation of the optic disc in glaucoma and diabetic retinopathy," in Medical Image Understand Annual Conference, (London, UK), pp. 23– 24, September 2004.

[3] Goldbaum, M.H Katz, N.P Chaudhuri, S. Nelson, M. "Image Understanding for Automated Retinal Diagnosis," Proceedings: The Thirteenth Annual Symposium on Computer Applications in Medical Care, pp. 756-760, 1989

[4] Huiqi Li and Opas chutatape (2004), 'Automated Feature Extraction in Color Retinal Images by a Model Based Approach', IEEE Transactions on Biomedical Engineering,Vol. 51, No. 2, pp.246-253

[5] KoseCemel ,2008.Automatic segmentation of age-related macular degeneration in retinal fundus images,Department of Computer Engineering, Faculty of Engineering, Karadeniz Technical University, 61080 Trabzon, Turkey

[6] Lowell J.,Hunter, Andrew Steel D., Basu A., Ryder R., Fletcher E., Kennedy L. (2004), 'Optic nerve head segmentation',IEEE Transaction on Medical Imaging, Vol. 23, No. 2, pp. 256-264

[7] M. Lalonde, M. Beaulieu, and L. Gagnon, "Fast and robust optic disc detection using pyramidal decomposition and haussdroff based templet matching," IEEE Transactions on Medical Imaging, vol. 11, pp. 1193–1200, November 2001

[8] Saleh, S, 2010. Image Segmentation by Using Thershod Techniques . *Journal of computing*, 2/5, 4.

[9] S. Kavitha, S. Kavitha ,(2011). "Automatic Detection of Hard and Soft Exudates in Fundus Images Using Color Histogram Thresholding ''in European Journal of Scientific Research ISSN 1450-216X Vol.48 No.3 (2011), pp.493-504

[10] S. Sekhar, W. Al-Nuaimy, and A. K. Nandi, "Automated localisation of optic disk and fovea in retinal fundus images," in 16th European Signal Processing Conference (EUSIPCO 2008), Lausanne, Switzerland. EURASIP, August 25-29,2008.

[11] The Difference Between Wet and Dry Age-Related Macular Degeneration - VisionAware . 2012. *The Difference Between Wet and Dry Age-Related Macular Degeneration - VisionAware* . [ONLINE] Available at:<http://www.visionaware.org/section.aspx?FolderID=6&SectionID=134&DocumentID=5972>. [Accessed 11 August 2012]

[12] Parvathi, S.S, (2007). Automatic Drusen Detection from Colour Retinal Images .*In Conference on Computational Intelligence and Multimedia Applications, 2007. International Conference on*. Sivakasi, Tamil Nadu, 13-15 Dec 2007. 377-381

[13] Youssif, A.H. A.R A. Ghalwash, Z. and Ghoneim, A. A. S. A."Optic disc detection from normalized digital fundus images by means of a vessels' direction matched filter," IEEE Transactions on Medical Imaging, vol. 27, pp. 11–18, January 2008.