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Segmentation of Optic Disc Using Thresholding Method from Retinal Fundus Images

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Abstract: Main objective of segmenting image is to convert the representation of an image into another format that is useful for analysis of image features and properties. Retinal image segmentation is an essential stage for retinal disease analysis and identification. Retinal image segmentation helps the ophthalmologists in detection of glaucoma eye disease. Glaucoma eye disease is one of the important causes for permanent vision loss. Early detection of glaucoma is important in order to prevent further progression of vision loss. Vertical cup-to-disc ratio is the important clinical parameter used for glaucoma disease detection and accurate segmentation of optic disc from retinal images is of great significance. This work presents three methods based on Thresholding for segmentation of optic disc region from retinal fundus images. The proposed methods were evaluated using DRIONS-DB dataset containing 110 images and HRF dataset containing 45 images. The performance metric boundary localization error is calculated by comparing each proposed method with the ground truth values. Results from the proposed methods shows that methods are less complex and efficiently works on all images.

Keywords: Segmentation, Optic Disc, Glaucoma, Thresholding, Fundus Images, Gamma Transformation.

1. Introduction

In medical field, Computer Aided Diagnosis plays an important role for diagnosis of diseases. Nowadays, it has become more powerful tool in ophthalmology field. Computer Aided Diagnosis provides the effective screening of image features to help the clinicians in diseases identification. The success of disease identification is based on effective analysis of image features which in turn depends on accurate image segmentation. But, accurate segmentation of an image is generally a very challenging problem. Therefore, accurate segmentation of optic disc from retinal fundus image plays the vital role in glaucoma disease detection. Figure 1 shown below depicts three methods, which are used in this proposed work for optic disc segmentation.

Threshold based method is a straightforward technique to segment retinal image based on intensity levels [1-3]. It is carried out either locally or globally. Local thresholding method is also referred as adaptive thresholding method. It works on threshold value, which varies over an image and based on the local characteristics of segmented regions. On another side, Global thresholding make use of the mask and segment the objects and background pixels by comparing with chosen threshold value.

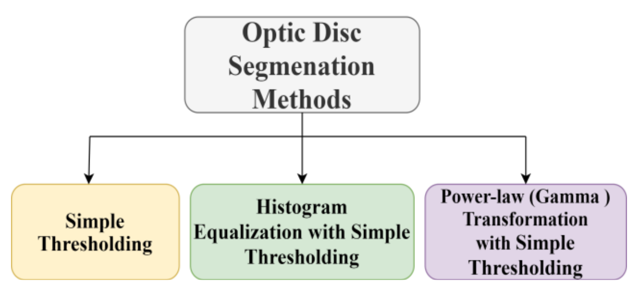

Figure 1. Optic Disc Segmenation Methods

2. Related Work

Ying Wang et al. [4] developed an approach for optic cup extraction and also developed the algorithm for optic disc extraction from retinal images. In this approach authors used the Two-Layer Level Set Method. Conducted the experiment on mild glaucoma, moderate

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glaucoma and severe glaucoma and obtained the moderate results

Elbalaoui et al [5] proposed a novel system for optic disc segmentation from retinal images. Authors presented the active counter method to extract the optic disc. Authors were used the publically available DRIVE and MESSIDOR databases images and obtained the good results. Proposed method consisting four major steps: Pre-processing, Optic Disc localization, Blood Vessel removal and Optic Disc segmentation. They used Sensitivity, Specificity and Overlapping score for performance evaluation.

R. Priyadharsini et al [6] developed a technique for optic disc segmentation. Authors used the feature detection and morphological techniques for disc extraction. Authors performed the image processing using histogram equalization and obtained the connected components. Later, circle detection Hough transform function was used to optic disc then disc boundaries were smoothed by morphological operations. Authors were used the DRISHTI-GS database for testing the proposed method.

S.VASANTHI et al [7] presented a method to extract optic disc from fundus images. Authors used the region-based active contour model for segmentation of disc part from the image. Authors preformed the image pre-processing to obtain the brighter and noise free image. Later, they used GVF model and C-V model for disc localization and extraction.

Manikandan T et al [8] used the Automatic Thresholding and Marker - Controlled Watershed Transformation methods for disc part extraction. Optic disc was segmented by thresholding method. Authors considered only 15 images for assessment of the proposed system.

Vijay M Mane et al [9] used circular Hough transform using morphological pre-processing to find the position of optic disc in the image. Later, disc area was segmented by watershed transformation. Authors conducted experiments on DRIVE database. The performance of the presented methodology was evaluated by using parameters sensitivity and overlap. The average sensitivity achieved by the method was 88% and average overlap achieved was 80%.

Muhammad Naseer et al [10] illustrated the glaucoma classification based on optic disc localization and segmentation using deep learning. Authors were illustrated the concepts in two stages. In the first stage authors extracted optic disc using Convolutional Neural Network (RCNN) and in the second stage authors classified the image into healthy or glaucomatous uses Deep Convolutional Neural Network.

Arunava Chakravarty et al [11] presented a novel approach to extract optic disc and cup boundaries using boundary-based Conditional Random Field formulation. Authors also estimated the depth of color fundus image and they concluded that estimated depth achieved a correlation coefficient of 0.80 with respect to the ground truth. Authors conducted experiment on DRISHTI-GS1 data set.

Ahmed Almazroa et al [12] proposed the new automated image processing system using level set method to extract optic disc from the retinal fundus images. Authors used the RIGA dataset images for testing purpose and obtained the moderate accuracy. Accuracy of proposed method was calculated by comparing the disc obtained from the proposed system with discs marked by the six ophthalmologists.

3. Proposed Methods

From the literature survey, it is found that there is several optical disc segmentation methods, most of them are ended up with poor results and also found that most of the work focused on only one method. This work presents the three categories of methods to extract optic disc from the fundus images.

A. Simple Thresholding (ST)

Pixel grey level is the most commonly used image property to represent the threshold. The intensity distribution function is given by:

$$M(p,q)=\begin{cases}1 & if \quad N(p,q)\geq T\\ 0 & if \quad N(p,q)<T\end{cases}$$

Where T is the threshold, N is the gray scale image, M is the segmented image, N (p, q) represents the intensity at position (p,q) in the image

Using two thresholds, T1<T2,

$$M(p,q)=\begin{cases}1 & if \quad T1\leq N(p,q)\leq T2\\ 0 & if \quad N(p,q)<T1 \mid N(p,q)>T2\end{cases}$$

Algorithm: optic disc segmentation using simple thresholding

Input: Test image, I

Output: Segmented optic disc from test image

Procedure:

1. Input a test image, I
2. Extract red, green and blue channel images from I
3. Set threshold T to 110
4. Apply threshold to green channel image
5. Perform the morphological image filling and closing operations on resulted image to obtain accurate optic disc

6. Mark the boundary of the disc using viscircles function
7. Extract the optic disc

B. Histogram Equalizationnits (HEQ) with Simple Thresholding

In this work, a Histogram based thresholding is used to segment the retinal image. Some of the pre-processing and post processing techniques are used along with Histogram based thresholding for accurate optic disc segmentation. Histogram is one image processing method which represents the pixels distribution of an image in the form of graph. The graph generated by the histogram illustrate the number of pixels belongs to each intensity value. A Histogram Equalization method is used for enhancing the image in order to obtain the better disc portion from the input image. The Histogram Equalization method improves contrast of an input image, which helps the segmentation process in the next stage. Contrast enhancement is accomplished by effectively stretching lower intensity range into higher intensity range. This method helps the lower local contrast areas to gain a higher contrast. Once the image is enhanced by the Histogram Equalization, simple thresholding is applied on enhanced image to extract the required area.

Algorithm: optic disc segmentation using Histogram Equalization and Simple Thresholding

Input: Test image, I

Output: Segmented optic disc from test image

Procedure:

1. Input a test image, I
2. RGB image I converted into grayscale image I
3. Calculate frequent counts, means occurrence of each pixel , freq
4. Calculate probability of each occurrence using freq, probf.
5. Initialize sum=0; no_bins=270;
6. Calculate cumulative distribution probability, probc, and histogram levelled image, hist for each probf
   sum=sum+freq
   probc=sum/numofpixels
   hist=round(probc*no_bins)
7. Obtain the binary image form I, hist, by applying simple Thresholding
8. Perform the morphological image filling and closing operations on resulted image to obtain accurate optic disc
9. Mark the boundary of the disc using viscircles function
10. Extract the optic disc

C. Power-law (Gamma) Transformation (PL) with Simple Thresholding

Power-law or gamma Transformation is one image enhancement technique. Main goal of image enhancement is to generate enhanced image, which provides more detailed and better contrast image as compare to non-enhanced image. It works on the transformation function as shown below

$$O = T(p)$$

Where p represents the input image pixel and O represents the output image pixel. T is an Enhancement/transformation operation that will transform each value in input image p to each value in output image O. Transformation function in power law transformations is expressed as given below:

$$O = c\, p \,\text{^}\gamma$$

Where c is constant value, which is in the rage of 0 to 1 and γ is called gamma, which is also a constant and it changes the contrast of the image. In this approach, Image enhancement completely based on Variation in the value of γ. Because of this property, the transformation is also known as gamma transformation. Once the image is enhanced by the gamma transformation, simple thresholding is applied on O to extract the required area.

Algorithm: optic disc segmentation using Gamma Transformation and Simple Thresholding

Input: Test image, I

Output: Segmented optic disc from test image

Procedure:

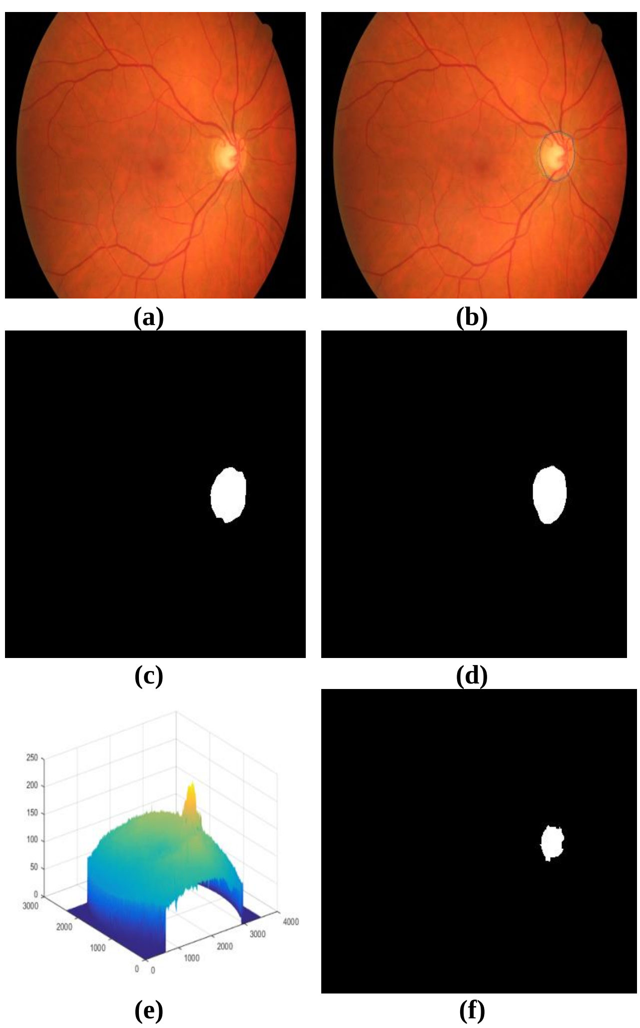
1. Input a test image, I
2. RGB image I converted into grayscale image I
3. Consider I in double format
4. Computing size m,n
5. Initialize c =1; gamma =4;
6. Compute O(p, q) = c * I(p, q).^ gamma
7. Obtain the binary image form O by applying simple Thresholding
8. Perform the morphological image filling and closing operations on resulted image to obtain accurate optic disc
9. Mark the boundary of the disc using viscircles function
10. Extract the optic disc

4. Results

Proposed methods are applied on publically available High-Resolution Fundus (HRF) and DRIONS-DB Image

Databases found at webpages https://www5.cs.fau.de/research/data/fundus-images/ and http://www.ia.uned.es/~ejcarmona/DRIONS-DB.html. High-Resolution Fundus database consists of 45 images with dimensions of 3504x2336, resolution of 72dpi, bit depth of 24. The DRIONS-DB consists of 110 fundus images with dimensions of 600x400, resolution of 96dpi, bit depth of 24. In this approach, Two Ophthalmologists optic disc area annotations are considered for efficiency evaluation. Dice coefficient is used to measure the performance [13]; it measures the similarity between two areas. i.e similarity between the optic disc region Y obtained by a segmentation algorithm and the ground truth region X marked by the Ophthalmologists. The Dice coefficient value ranges from 0 to 1. Higher coefficient value (near to 1) means higher the accuracy of proposed method.

$$\text{Dice} = \frac{2 * Area(X \cap Y)}{Area(X) + Area(Y)}$$



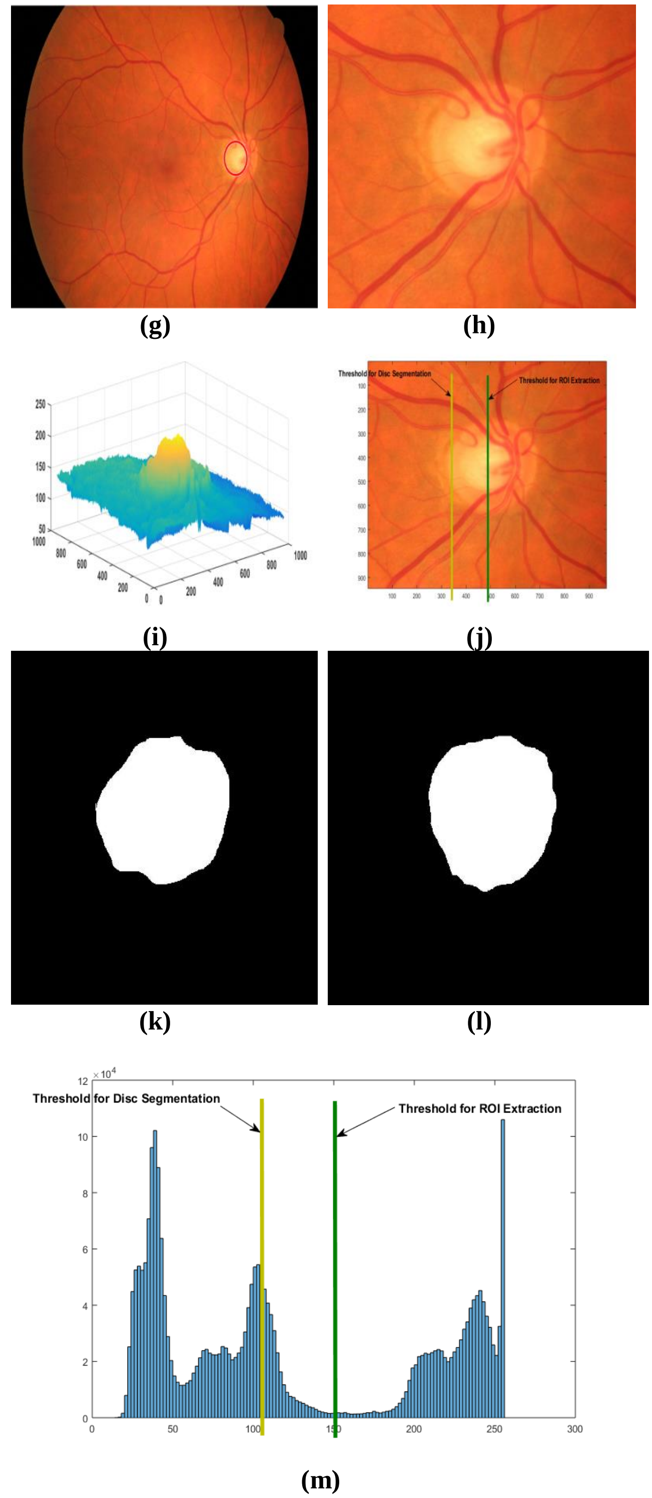
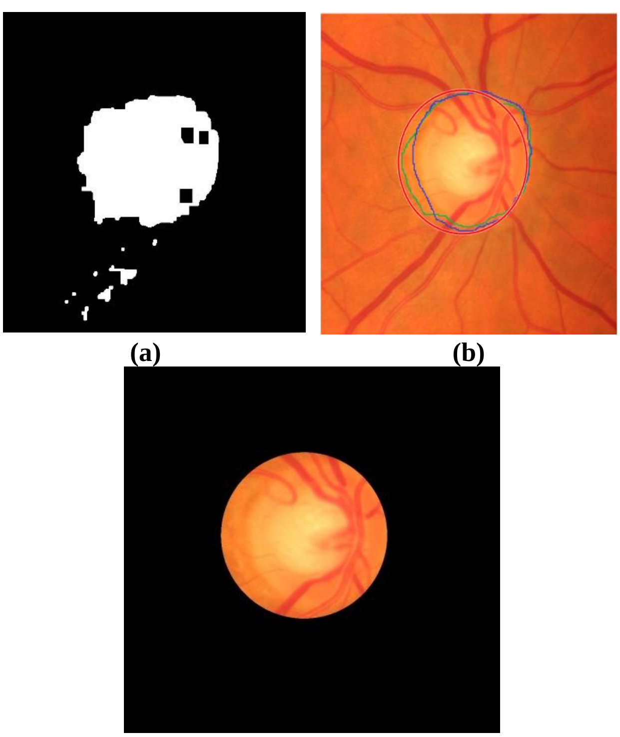


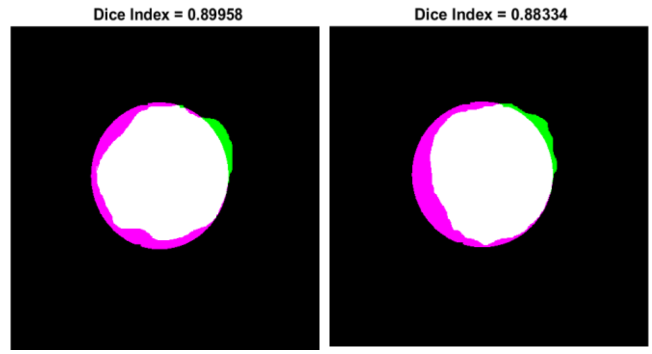
Figure 2. Input image and ROI

Figure 2 shows the information related to input image and Region of Interest (ROI). Figure 2 a) illustrates the Fundus eye image taken from HRF dataset. Same image is used for testing the proposed systems. Figure 2 b) illustrate the optic disc regions marked by two ophthalmologists. The green line represents area marked by the ophthalmologist 1 and the blue line represents the disc area marked by ophthalmologist 2. After capturing eye image of patient using fundus camera, ophthalmologists marked the disc regions. figure. 2 c) illustrates segmented optic disc using imfreehand function (marked by ophthalmologist 1) for similarity testing with each of the proposed method. Figure 2 d) illustrates the segmented optic disc using imfreehand function (marked by ophthalmologist 2) for dice coefficient calculation with disc area generated by each of the proposed method. Figure 2 e) illustrates density distribution graph of fundus image. Figure 2 f) illustrates the highest intensity area identified for ROI Extraction by setting threshould to 150 on green channel image. Figure g) illustrates the selected area in fundus image for ROI Extraction. Figure 2 h) illustrates Region of Interest (ROI) extracted from the fundus image using centroid point obtained from the selected area. 960x960 ROI extracted using centroid point. Figure 2 i) illustrates density distribution graph of ROI. Figure 2 j) illustrates the scaled ROI data with threshould used for ROI extraction and threshould used in simple threshould method to extract optic disc (110). figure 2 k) illustrates disc area extracted from ROI, marked by ophthalmologist 1. Figure 2 l) illustrates disc area extracted from ROI, marked by ophthalmologist 2. Figure 2 m) illustrates histogram of ROI



(a) **(b)**

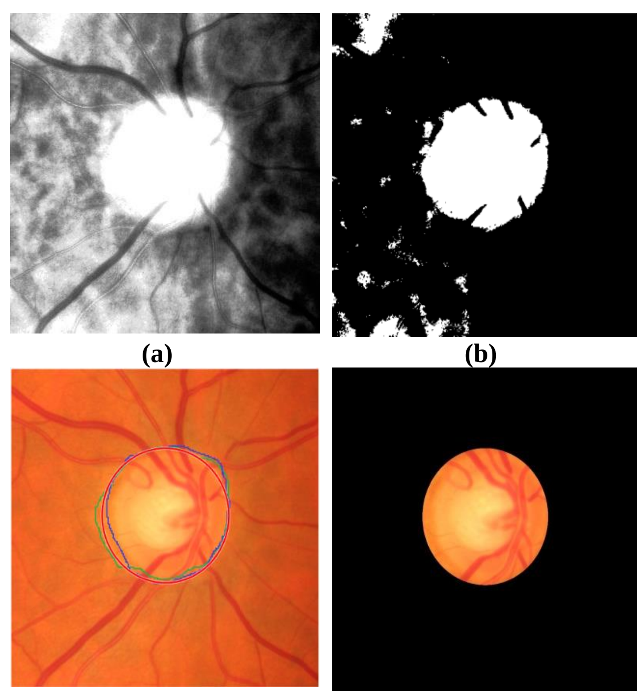
(c)



(d) **(e)**

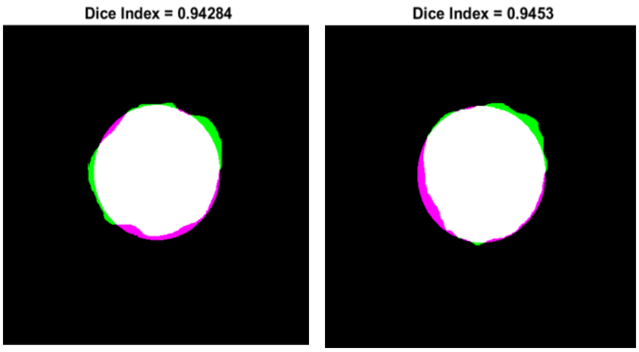
Figure 3. Simple Thresholding results

Figure 3 a) illustrates the disc area selected by simple thresholding, threshold is set to 110 to extract the dis area. Figure 3 b) illustrates the optic disc regions marked by two ophthalmologists (green line: ophthalmologist 1, blue line: ophthalmologist 2) and proposed method (marked in red line) on second ROI (960x960) which is extracted from ophthalmologists annotated image. Figure 3 c) illustrates the segmented optic disc from ROI. Figure 3 d) illustrates the dice coefficient obtained for ophthalmologist 1 marked area and proposed system extracted area. Figure 3 e) illustrates the dice coefficient obtained for ophthalmologist 2 marked area and proposed system extracted area



(a) **(b)**

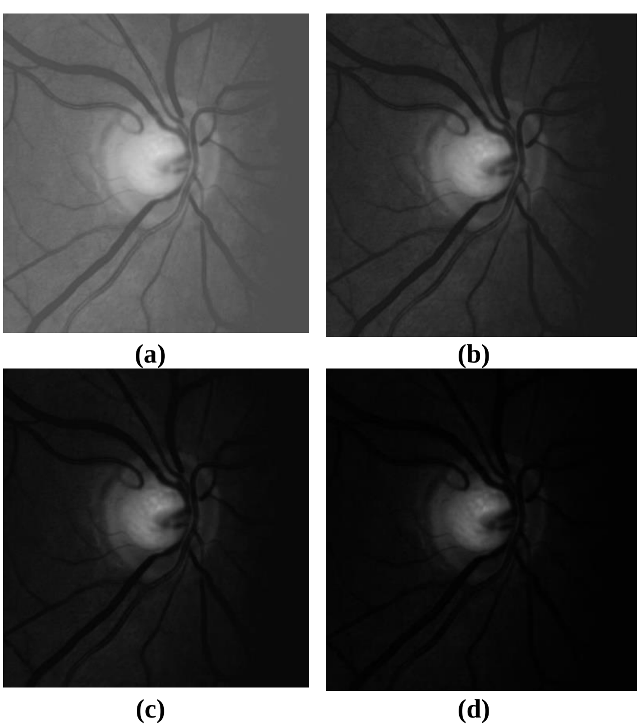
(c) **(d)**

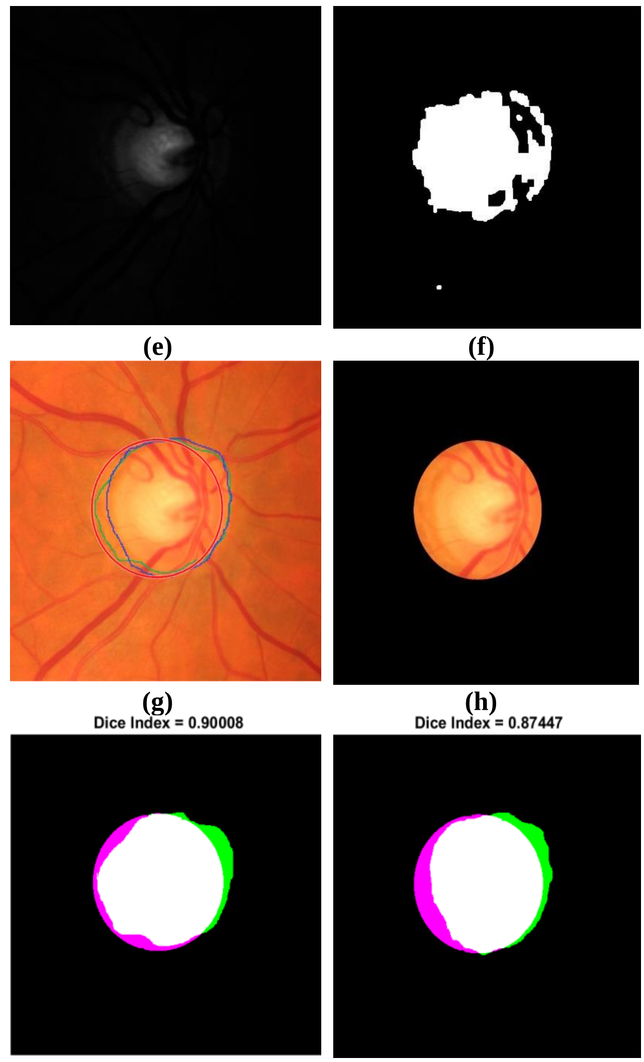


(e) **(f)**

Figure 4. Histogram Equalizationnits with Simple Thresholding results

Figure 4 a) illustrates the Enhanced image using Histogram Equalization. Figure 4 a) illustrates disc area selected by simple thresholding. Figure 4 c) illustrates the optic disc regions marked by two ophthalmologists (green line: ophthalmologist 1, blue line: ophthalmologist 2) and proposed method (marked in red line) on second ROI (960x960) which is extracted from ophthalmologists annotated image. Figure 4 d) illustrates the segmented optic disc from ROI. Figure 4 e) illustrates the dice coefficient obtained for ophthalmologist 1 marked area and proposed system extracted area. Figure 4 f) illustrates the dice coefficient obtained for ophthalmologist 2 marked area and proposed system extracted area





(i) **(j)**

Figure 5. Gamma transformation with Simple Thresholding results

Figure 5 a) illustrates the Enhanced image using gamma transformation with gamma =1. Figure 5 a) illustrates the Enhanced image using gamma transformation with gamma =2. Figure 5 c) illustrates the Enhanced image using gamma transformation with gamma =3. . Figure 5 d) illustrates the Enhanced image using gamma transformation with gamma =4. Figure 5 e) illustrates the Enhanced image using gamma transformation with gamma =5. Figure 5 f) illustrates the disc area selected by simple thresholding for the value gamma=4. Figure 5 g) illustrates the optic disc regions marked by two ophthalmologists (green line:, ophthalmologist 1, blue line: ophthalmologist 2) and proposed method (marked in red line) on second ROI (960x960) which is extracted from ophthalmologists annotated image. Figure 5 h) illustrates the segmented optic disc from ROI. Figure 5 i) illustrate the dice coefficient obtained for ophthalmologist 1 marked area and proposed system extracted area. Figure 5 j) illustrates the dice coefficient obtained for ophthalmologist 2 marked area and proposed system extracted area

Table I illustrates the Average Dice Coefficient obtained for various proposed methods and ground truth value of Ophthalmologist 1 on HRF and DRIONS-DB dataset images, also illustrates the average of each method (considering both dataset). Figure 6 shows the corresponding bar chart. Table II illustrates the Average Dice Coefficient obtained for various proposed methods and ground truth value of Ophthalmologist 2 and average on each method. Figure 7 shows the corresponding bar chart.

TABLE I. AVERAGE DICE COEFFICIENT FOR OD CONTOUR DETECTION W.R.T OPHTHALMOLOGIST 1

Dataset	Dice coefficient obtained for Ophthalmologist 1 and proposed systems		
	ST	***HEQ***	***PL***
HRF	0.8569	0.9503	0.8469
DRIONS-DB	0.8243	0.9296	0.7960
Average	0.8406	0.9399	0.8214

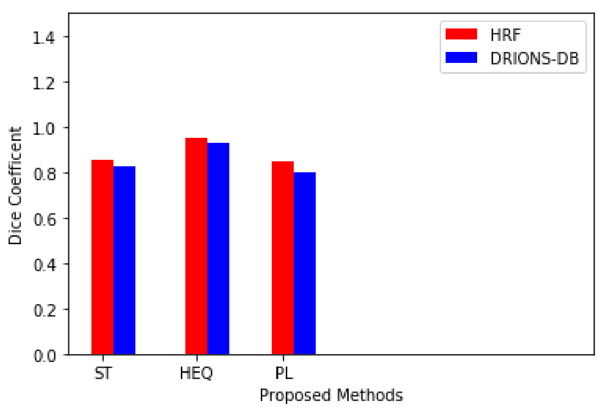


Figure 6. Dice coefficient obtained for Ophthalmologist 1 marked area and Proposed Systems

TABLE II. AVERAGE DICE COEFFICIENT FOR OD CONTOUR DETECTION W.R.T OPHTHALMOLOGIST 2

Dataset	Dice coefficient obtained for Ophthalmologist 2 and proposed systems		
	ST	***HEQ***	***PL***
HRF	0.8201	0.9462	0.8398
DRIONS-DB	0.8093	0.9198	0.7751
Average	0.8147	0.9330	0.8074

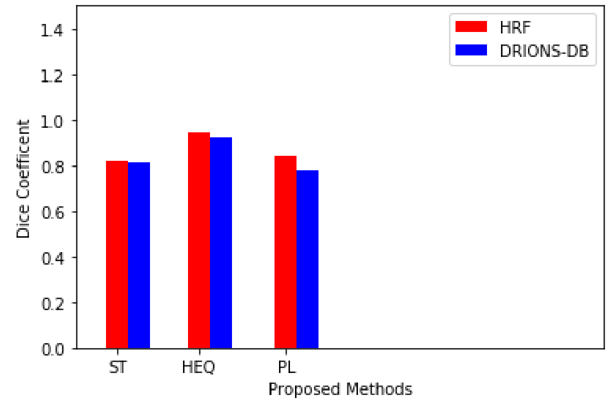


Figure 7. Dice coefficient obtained for Ophthalmologist 2 marked area and Proposed Systems

Table 3 illustrates the average Dice Coefficient obtained for each of the proposed method by considering Ophthalmologist 1 and Ophthalmologist 2 averages.

Ophthalmologist	Proposed Systems		
	ST	***HEQ***	***PL***
Ophthalmologist 1	0.8406	0.9399	0.8214
Ophthalmologist 2	0.8147	0.9330	0.8074
Average	0.8276	0.9364	0.8144

5. CONCLUSION:

This work presented methods for optic disc extraction from fundus images. Proposed techniques are tested on HRF and DRIONS-DB databases. The region of interest detection and extraction of region of interest (ST, HEQ and PL) methods are presented for optic disc extraction. The result obtained from the proposed methods illustrates the better performances. Furthermore, proposed methods are applied to all types of retinal images including healthy as well as glaucoma images. The proposed methods ST, HEQ and PL works well on HRF data sets with an dice coefficient 83%, 95%, 84%, respectively and 81%, 92%, 78% respectively on DRIONS-DB data sets, these efficiency makes proposed methods are suitable for automatic extraction of optic disc from fundus images.

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