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A COMPARATIVE APPROACH TODETECT GLAUCOMA IN RETINAL IMAGES

M.AntonyAmmal[1], Dr.D.Gladis [2], Dr.AtheekShaik [3]

[1] *Research Scholar, Presidency College (A), University of Madras, Chennai*
[2] *Research Supervisor, Principal, BWC (A), University of Madras, Chennai*
[3] *Ophthalmologists, Fathima Eye Clinic, Chennai,*

Abstract

Glaucoma is an eye ailment which is instigatedgenerally due to arise in the intra ocular pressure in the eye and affects the vision of the person if not treated at the early stage. Due to its slow progressiveness and often with no symptom of its own, many people are ignorant of this until it reaches a complicated stage. As it is preventable and not curable, there arises an urgent need to create awareness about glaucoma among people. With periodical screening of retina, there is a possibility of starting treatment at an early stage so as to avoid loss of sight. The existing imagingmodalitiesare expensive and hencean economical method of diagnosis isrequired. The aim of this article is to compare the performance of two pixel based techniques, in which one appliesan intensity based technique and the other applies a distance based clusteringtechnique insegmenting the optic disc and optic cup from the retinal fundus image and in calculating cup to disc ratio so as to helpidentify glaucoma in a cost efficient way using MATLAB.

Index Terms – *Glaucoma; Optic disc; Optic cup;Cup to disc ratio; Thresholding; K-means clustering*

1. INTRODUCTION

Glaucoma is the second reason for loss of vision in the worldand is estimated to impact approximately 80 million people in the year 2020. Most patients are unaware of this visual disruption because of its gradual progressing existence before the disease reaches an advanced stage.Early identification of glaucomachange is crucial to reducing the risk of significant impairment[1]. The population of the blind is estimated to rise to 1.5 crore by the year 2020. Diseases of the retina have had low priority in blindness prevention programs in developing nations. These diseases are responsible for 4.7% of all cases of blindness in India and are expected to become more common in future. The number of eye doctors in the country definitely needs to increase. There is a need to encourage faster and precision-based systems of medical treatment. With rapid diagnostic, medical and surgical advances in managing retinal diseases, treatment is becoming more affordable [2].The keyeffect of glaucoma is the failure of the human eye to sustain aconventionalstability between the amount of fluid generated and the amount of fluid drained out. The fluid so-calledas aqueous fluid is produced by a layer of cells behind the iris. Increasing eye fluid within the eye causes damage to the retina which results in glaucoma.Usually the fluid generated is balanced by the fluid draining out, but if there is blockage or if toomuch aqueous fluid isproduced then the eye pressure, theintraocular pressure (IOP)will increase. A rise in IOP can damage the retinal optic nerve quickly [3].

Glaucoma is generally diagnosed by a combination of tests, which may include intraocular pressure measurement, visual field testing, retinal fundus photography, Heidelberg retinal tomography(HRT),scanning laser ophthalmoscopy and Optical Coherence Tomography(OCT)[1].In general,the real-time examination of the ailment of the eye by the ophthalmologist isby means of an ophthalmoscope, which is a proficient procedure carried out at marginalcost comparatively and versatile but the images cannot be stockpiled.Hence retinal fundus photography is an alternative multiuse approach extensively and often applied forscreening glaucoma, Longitudinal evaluations are also acquired as an analytical archivefor further eye ailments. Due to its reasonablymodestpractice and budget, it is appropriate for screening studies, while HRT and OCT are expensive methods of screening glaucoma. The fundus photography of the retina is depicted in Fig.1.

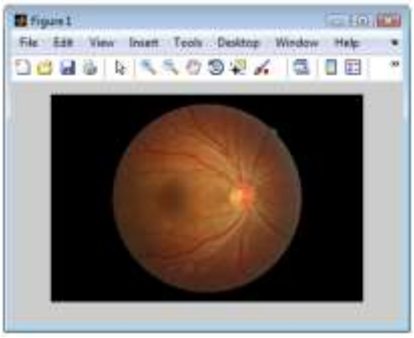

Fig.1. Fundus image of retina

Computerized analysis can also be useful for quantitative measurements of various diagnostic parameters for consistent assessment and follow-up examinations [1]. Medical image processing is a boon to the field of medicine, where medical images are processed with the help of computer and the results generated help in diagnosing in a better way. This paper compares the performance of thresholding and k-means clustering techniques in segmenting the optic disc and optic cup from the retinal image in order to compute the cup to disc ratio. Section II discusses the methodology of classifying the image as either healthy or glaucoma suspected by usingcup to disc ratio (CDR). Section III mentions the statistical analysis followed by result analysis and conclusion in section IV and V respectively.

2. METHODOLOGY

Ininterpreting retinal fundus images, it is essentialfor the physicians to observe several signs of aberrations. The computer assistedimage analysis deepens the accuracy and enhances the efficiency of identification of diseases, as well assist the physician by reducing the workload.In order to differentiate the retinal image as healthy or glaucomatous, extraction of optic disc and optic cup from the fundus image is essential. Nontrivial image segmentation is one of the hardest tasks in image processing[4].As for segmentation, numbers of algorithms for extraction of specific features for discretepositions is instant. But carefulness is prerequisite in determining and implementing the right algorithm apt for retinal structure medical analysis in a precise and unambiguous way[5].Most image handling systems follow the collectivephases like pre-processing, processing and post-processing and the tasks carried out in every stage be at variancecentered on the application. This section compares and discussestwo segmentation approaches namely grouping the pixels based on intensity called thresholding techniqueand grouping the pixels based ondistance called clusteringtechnique.

IntensityAnalysis Technique:

Intensity analysis techniquesegregate the images rightly into regions centered on intensity values which can very well discriminate foreground from background. If the intensity variations are high, the effectiveness of the segmentation between object and background will be prominent. Thresholding is one such techniqueideal for real time applications with the goal of extracting the desired features from the image by choosing the right pixel with the intensity threshold T, to meet minimum segmentation error.

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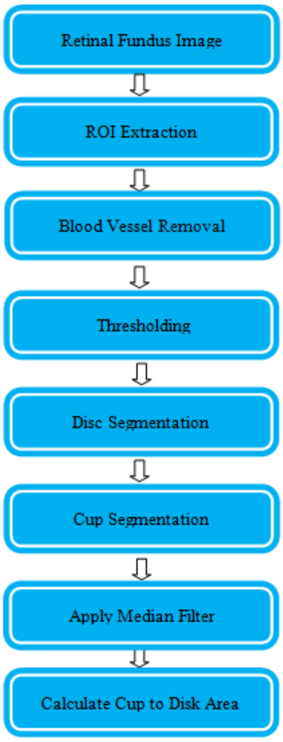

Fig.2. Flowchart of ThresholdingTechnique

The flowchart in Fig.2 describes the methodology applied here in segmenting the optic disc and optic cup.ROI extraction and blood vessel removal are the preprocessing stages here while median filtering is a post processing stage.

ROI Extraction:

The 2D retinal fundus image is an RGB image as shown in Fig.1. Retinal blood vessels pass through the optic nerve head (ONH),enter the eyeball and run inside the retinal nerve layer.The ONH has an oval nature, where large vessels converge on a retinal imageand appears as a bright region. It is composed of millions of retinal nerve fibers that packaged together and exit to the brain through the optic disc located at the back of the eye [6].Impulses from the retina in the eye are carried out by optic nerves to the brainfor vision.To speed up processing and to improve accuracy, the fundus image is down sampled. The brightest region of a certain size of the retinal image is located and extracted as Region of Interest (ROI). Fig.3 visualizes ROI of a healthy and glaucoma image. The RGB image is preprocessed into basic color channels and the appropriate color channel is chosen for proper segregation of optic disc and cup.

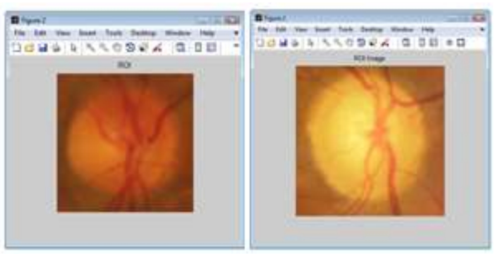

Fig.3.ROI

Blood Vessel Removal:

The visibility of blood vessels in the gray converted ROI affects the correctness of the segmentation outcomes. Blood vessel removal is needed in order to fragment the optic disc and cup in a right way. Application of mathematical morphology based technique is imperativein removing the blood vesselsMorphological closures reduce unsolicited edifices and continue to smooth parts of object contours, fuse narrow breaks and long thin gulfs, close small holes and fill gaps[4]. A morphological closure of set **A** with a small kernel scale **B** for replacement of the blood vessel is shown in (1).

$$A \bullet B = (A \oplus B) \ominus B \quad (1)$$

$$A \oplus B = \{x: B_x \cap A \neq \emptyset\}$$

$$A \ominus B = \{x: B_x \subseteq A\}$$

The image before and after blood vessel removal are represented in Fig.4a and 4b respectively.

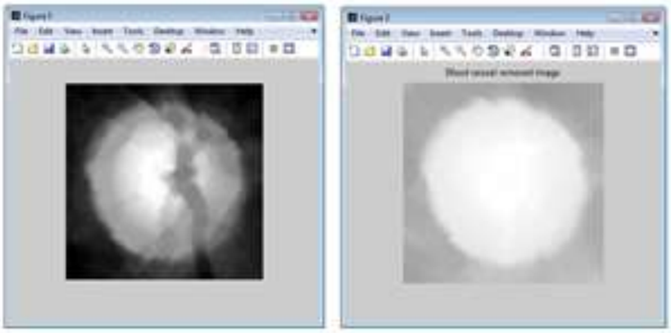

Fig.4 (a) Gray Image (b) Blood Vessel Removed Image

Optic disc and optic cup segmentation:

The optic nerve head is referred as the optic disc and the state of the dent within the optic disc termedas the opticcup which is in generallesser in size in proportion to the opticnerve head.Optic disc and cup segmentation is to extract therequired place in the ROIthat fulfill a condition. The mean thresholding technique whichperforms the transformation of an input gray scale image g(x, y) to a segmented output binary image f(x, y) [4] by selecting a suitable threshold valueT is applied as given in (2) and the segmented optic disc is shown in Fig.5 (a).

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

Due to the blood vessel removalpreprocessing, the extracted optic disc have a smooth boundary.

Generally optic cup segmentation process is complex compared to optic disc segmentati on, due to the bundling of the blood vessels near the cup region. Green channel best suits segmentation of optic cup and Fig.5 shows a segmented image.

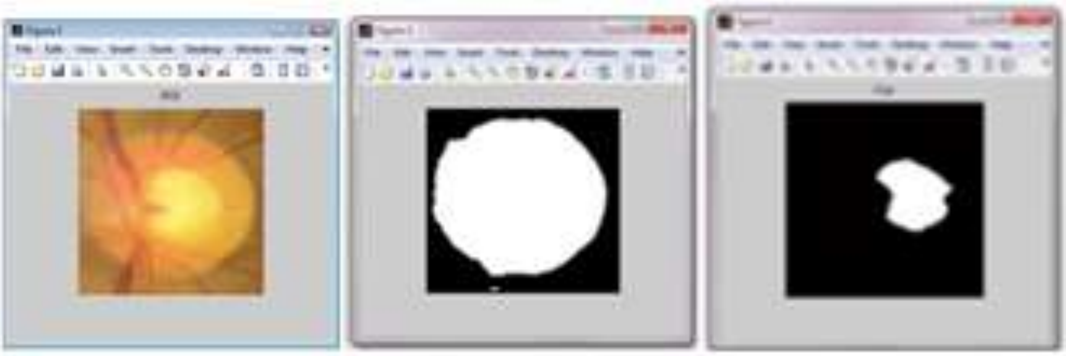

Fig.5(a) ROI (b)Optic disc (c)Optic cup

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Median Filter:
Few pixels of the segmented image may be missed. To remove outliers and to smooth the boundaries the non-linear median filter is applied.
It possessevident noise reduction capabilities, with slightly less blurriness than linear smoothing filters of comparable scale[4] and it is mathematically expressed as:

$$f(x, y) = median\{g(s, t)\} \qquad (3)$$

This defines the generalizations of dilation and erosion operators. The segmented and median filter applied optic disc and optic cupare represented in Fig.6.

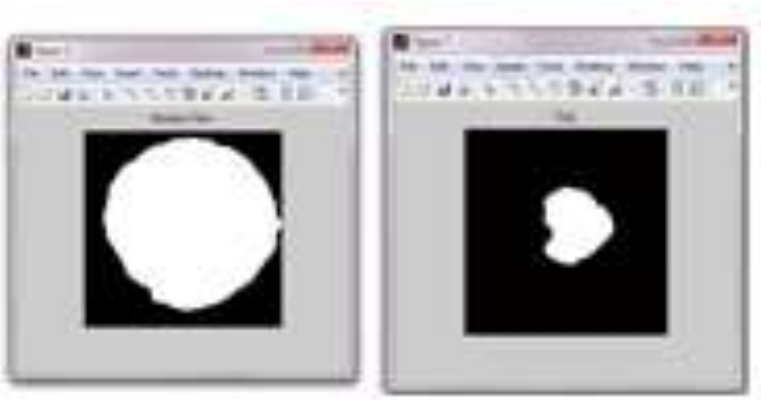

Fig.6(a) Optic Disc(b) Optic Cup

Cluster Analysis Technique:
Cluster analysistechnique labels the data into clusters.A cluster refers to an agreed set of data points aggregated together because of certain similarities.

The more similarities between cluster data, the greater the chances of particular data items belonging to a specific category.

Various clustering algorithms are available, and clustering by k-means is a popular unsupervised algorithm in machine learning.

Distance metrics play a key role in the cycle of clusteringand k-means applies to data averaging when locating the centroid.

Unsupervised algorithms use only input vectors to make inferences from datasets without reference to known or labeled outcomes.

It is a statistical clustering algorithm that is basically used for its simplicity of implementation, convergence speed and generating clusters of moderately high quality[7].

Unsupervised learning method doesn’t have the ground truth to compare the output of the clustering algorithm to evaluate its performance. It tries to investigate the structure of the data by grouping the data points into distinct subgroups.

K-means algorithm is used in a broad variety of applications, including image segmentation and the methodology adopted in segmenting optic disc and cup is represented in Fig.7.

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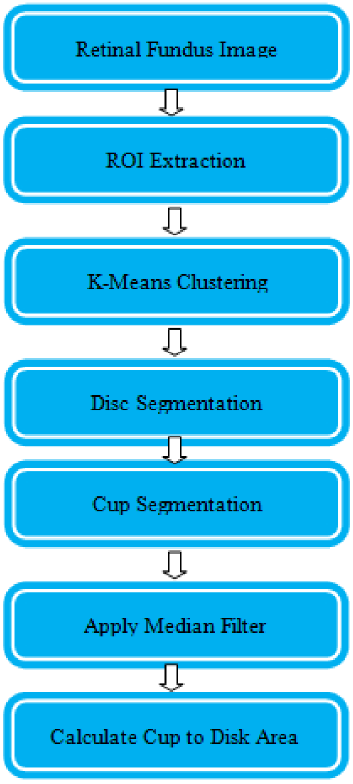

Fig.7. Flowchart of K-Means Technique

It classifies a given data set into a 'k' disjoint clusters and it generatesdissimilar cluster effect for the different 'k' values. A hard clustering algorithm generates clusters that are non-overlapping.It is an iterative refinement method which minimizes the sum of squared distances between all points and the cluster midpoint[8].

$$J = \sum_{j=1}^{k} \sum_{i=1}^{n} \left\| x_i^{(j)} - c_j \right\|^2 \quad (4)$$

The clustering processin k-meansalgorithm is performed in twophases. It calculates the 'k' centroid in the first phase trailed by assigning each point to the cluster that has the nearest centroid from the respective data point in the second phase. There are few methods to determine the distance of the nearest centroid and Euclidean distance is one of the most widely used method[8]. Now recalculate the 'k'centroid and repeat the second phase until no furtherchange of centroid. Thus after refinement of the data clusters the outcomes results insmaller intra-cluster distance comparedwith larger inter-cluster distance.The segmented images by k-means clustering method is shown in Fig.8.

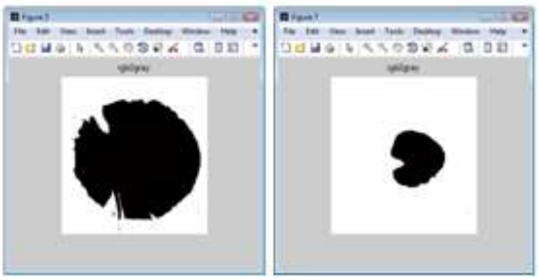

Fig.8(a)Optic Disc (b) Optic Cup

The median filtering is applied as a post processing step in order to enhance the quality of the image and it is evident in Fig.9.

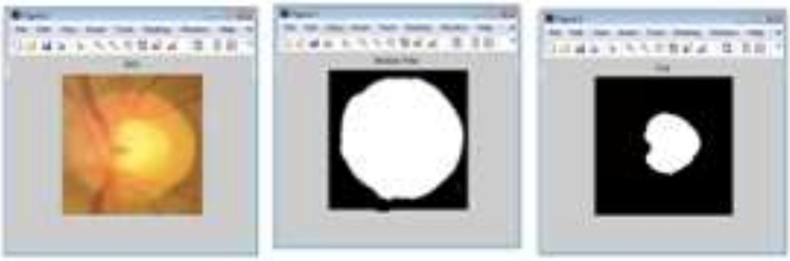

Fig.9(a) Optic Disc (b) Median Filtered (c) Optic Cup

Cup to Disk Ratio Calculation (CDR):

The accuracy of segmentation determines the potential success or failure of computerized diagnostic measures. Considerable care should be taken to improve the probability of accurate segmentation [4].Segmented optic disc and optic cup are used in the computation of Cup to Disc Area and VCDR whichare the prominent parameter used in detecting glaucoma.

(i) Cup to Disc Area Calculation:

It indicates the proportion of cup area occupied within the disc area and calculated as in (5).

$$Cup\ to\ Disc\ Area = \frac{Cup\ Area}{Disc\ Area} \quad (5)$$

Cup Area and disc area are figured by summing the pixels in the segregated cup and disc respectively.

(ii) VCDR Calculation:

VCDR is considered as the proportion of perpendicularlength of the optic cup to perpendicularlength of the optic discand calculated as in (6).

$$VCDR = \frac{VCD}{VDD} \quad (6)$$

Statistical Analysis

Statistical software program package (SPSS)was used for the analysis.Concordance analysis, paired comparison were conducted and 95% confidence intervals were calculated. The difference between the algorithmswas analyzed using paired samples *t* test.

3. RESULTS AND DISCUSSION

The proposed methodologies have been developed using MATLAB 2018a. The algorithmswere tested for healthy and glaucoma suspected images taken from Corrected Bin Rushed folder of Retinal Fundus Images for Glaucoma Analysis (RIGA) dataset [9].
The dataset contain both normal and glaucomatous images of size 2376*1584 pixels. These images were added to the database in May 21, 2018. The images are saved in .jpg file format [9].
The optic cup and disc borders of these photographs were labeled and manually annotated by six professional ophthalmologists using a tablet and a precise pen individually [9]. In order to evaluate the discussed algorithms based on vertical cup to disc ratio, the two parameters vertical disc diameter and vertical cup diameter were calculated for the manual

markings. This helps in predicting the given image as either healthy or glaucoma suspected based on the values obtained from the features extracted.

CDR Vs VCDR:

Table 1 shows the values computed using VCDR by both the methods for the same sample image.

TABLEI.:RESULT ANALYSIS

	VCDR
Ophthalmologist1	**0.49**
Ophthalmologist2	**0.48**
Ophthalmologist3	**0.49**
Ophthalmologist4	**0.57**
Ophthalmologist5	**0.46**
Ophthalmologist6	**0.45**
Thresholding	**0.32**
K-Means Clustering	**0.48**
	CDR
Thresholding	**0.16**
K-Means Clustering	**0.25**

The comparison of VCDR and CDR is shown in Fig.10. CDR-T and CDR-K in chart represents values computed by thresholding and K-means methods. It is obvious that VCDR computed by (6) is more accurate than CDR by (5), because of counting the pixels in the segmented optic cup which is not a complete one. Hence it is evident that VCDR is the best parameter compared with CDR.

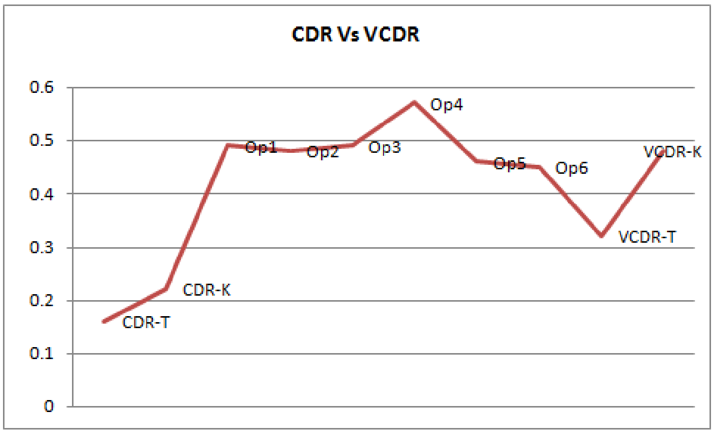

Fig.10. CDR Vs VCDR

Threshold Vs. K-Means Algorithm:

The six ophthalmologists manual labeling of a sample image and also the comparison effect of automated segmentation of threshold and k-means algorithm with the automated marking of both algorithms is shown in Fig.11.

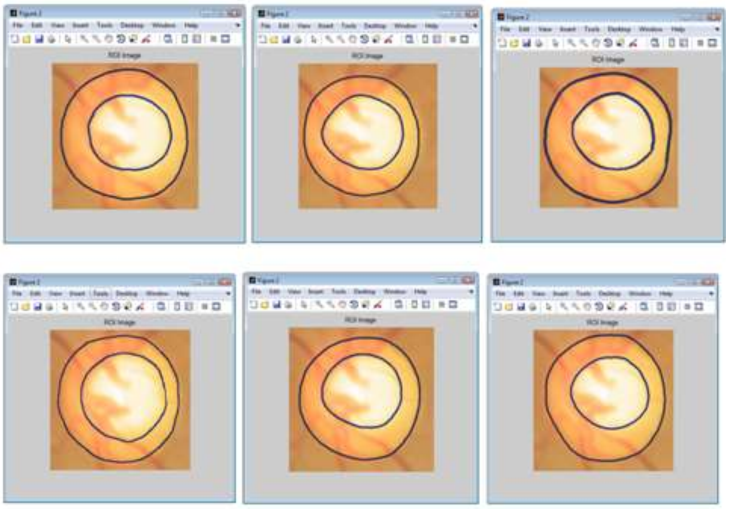

Fig.11(a). Sample results of six Ophthalmologist marking

Fig. 11(b) Thresholding Algorithm Marking

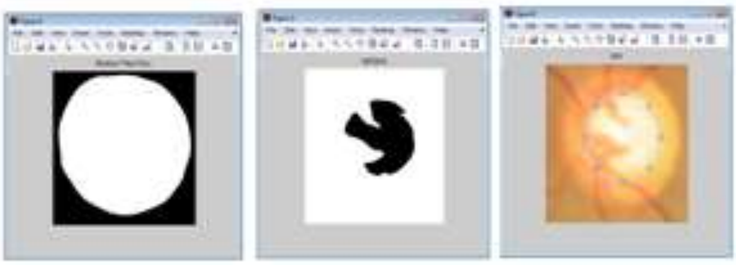

Fig. 11(c) K-Means Algorithm Marking

Individuals with and without optic nerve damage have optic nerve cupping but individuals with glaucoma tend to have a higher cup-to-disc ratio [6].As the size of cup increases, so as the ratio. Large cup size leads to larger ratio and finally results in vision loss.
The analysis of the healthy and glaucoma images are displayed in Fig. 12(a) and Fig.12(b) respectively. Fig.12(a)shows the comparative graph of proposed algorithms and ophthalmologists' prediction in groups for the healthy images.

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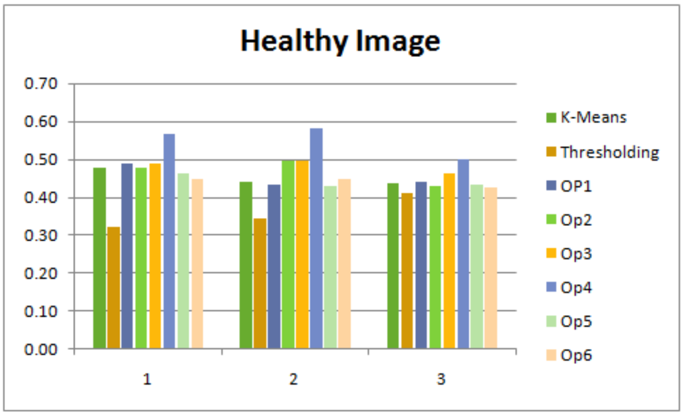

Fig.12(a)Performance Analysis of healthy images

An image is categorized as either normal or glaucoma suspected based on VCDR. The ratio of cup to disc approximately ranges from 0.2 to 0.9. In thehealthy or normal image, the ratiois less than 0.5 and in the glaucoma image it is greater than 0.5. Fig.12 (b) displays the comparative graph of glaucoma image.

Fig. 12(b)Performance Analysis ofGlaucoma images

The algorithms worked well for good clarity fundus images compared with less clarity images. The presence of blood vessels in complicated view reduces the quality of images [10]. Both the algorithms were tested on 32 sample images and the accuracy of the algorithm was therefore evaluated by each of the six ophthalmologists on the basis of the markings [10] for each sample and hence results in processing of 198 images. Thresholding technique is computationally simple and inexpensive and fast with little or minimum intervention [11] and widely used and K-Means clustering technique is a simple, fully automatic, accurate and fast.

Visual Comparison of Segmentation approaches:

It reflects how every ophthalmologist agreed with others performance. It is apparent that ophthalmologist four differs in most images comparatively while others were nearly similar. It is observed that though the performance of both the algorithms in predicting the results as either healthy or glaucomatous were significantly indifferent, the accuracy in segmenting the images is obviously different. K-means showed a performance similar to ophthalmologist while thresholding be deficient in segmentation.
In clinical practice even small difference in value should be considered for more accurate prediction. Hence it is evident that K-Means outperforms thresholding technique in segmentation.

Statistical Comparison of Segmentation approaches:

To statistically verify the difference between two measurements, The Paired Samples 't' Test is used as it can equate the means of two linked units with a continuous outcome which is normally distributed[12].

$$t = \frac{\overline{X}_D - \mu_0}{s_D/\sqrt{n}}$$

Where S_D- standard deviation and n- the number of samples.

The tenacity of the test is to conclude whether there is statistical substantiation that the meandissimilarity between paired observations on a given outcome issignificantly different from zero [12].

PairedSamples't'Statistics gives univariate descriptive statistics like mean, sample size, standard deviation, and standard error for each variable.Paired SamplesCorrelation shows the bivariate Pearson correlation coefficient with a two-tailed test of significance for each pair of variables. Paired Samples't' Test gives the hypothesis test results.A '*P'* value of less than 0.05 was considered to indicate a significant difference. Both methods showed significantdiagnosis ratio, but k-means method showed higher concordance with Ophthalmologists results.

TABLE II.: PAIRED SAMPLES 'T' TEST

Paired Differences							Sig. (2-tailed)
			95% Confidence Interval of the Difference				
μ	σ	$\sigma_{\bar{x}}$	Lower	Upper	t	df	
.258	.445	.080	.095	.421	3.230	30	.003

The Paired Samples Correlation table adds the information that both methods scores are significantly positively correlated. From the resultsstates, it is stated that(i) both scores were positively correlated ($r = 0.589, p < 0.001$)(ii) there was a significant average difference between bothscores ($t = 3.230, p < 0.001$) (iii)on average, K-Meansmethod was0.258 points higher than Thresholding method (95% CI [0.95, 0.421]).

Thus the ability of the algorithm is compared by the accuracy and it is apparent that k-means shows close proximity with ophthalmologist's results.To get the better performance, this algorithm can be analyzed with more samples.

4. CONCLUSION

Routine observation of retinal examination of fundus image is a cost effective and finest method for screening glaucoma and when done in proper manner, has the potential to reduce vision loss of the patients. The usage of this tool is emphatic in the elucidation of glaucoma and can facilitate substantially to the welfare of the people in a financial viable way. So before the vision gets blurred, they can get treatment from ophthalmologist. The correctness of this method is evaluated with the ophthalmologist prediction. The future enhancement can apply other machine learning techniqueswith more functions to segment images with disc abnormalities like peripapillary atrophy and tilted discs.

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