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Alternative Approach of Segmenting Optic Disc for Glaucoma Detection

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***Abstract*—Glaucoma is a disease that affects the Optic Nerve Head (ONH), which tends to permanent blindness and the pressure on vision got increased. The new proposed methodology explains about the glaucoma disease detection analysis with the retinal fundus image. The optic disc detection and segmentation plays a vital role in glaucoma diagnosis and is carried out by the edge detection method with morphological preprocessing techniques. The advantage of this method is to diagnose the noise from the background and reduced with low frequency. Blood vessel extraction detecting the change in retinal structure that separate the images by using the clustering method. This paper provides the detail about various segmentation techniques to separate the desired objects from the retinal images. Thus, performance analysis of glaucoma disease luminosity and contrast normalization is done by using multiscale retinex algorithm and segmentation is done and obtained the maximum performance compared to traditional Canny edge detection methodology.**

***Index Terms*— Glaucoma, Optic-Disk segmentation, preprocessing, blood vessel extraction, edge detectors.**

I. Introduction

Glaucoma is an eye disease that causes gradual loss of vision, which leads to the optic nerve got gradually damaged. The symptoms will be detected only after this disease is quite advanced, and so the glaucoma is also called as “the silent thief of vision”. Overall, around 80 million peoples were affected on 2020 [1], by glaucoma. At the beginning of glaucoma loss of peripheral or side vision occurs, it damages our optic nerve head (ONH). The ONH is located in behind the eye, it is also known as second cranial nerve. The optic nerve is the part that possesses the information from the visual to the brain world. Glaucoma has divided into two major types they are Primary open-angle glaucoma and Angle-closure glaucoma. There are many forms of glaucoma that have no signs until the advanced stage. When the glaucoma disease occurs, it increases the pressure in our eye called Intraocular pressure (IOP) that can cause a total blindness or even complete vision loss within a few years.

The Glaucoma symptoms and signs are varying depends on their condition [2]. The two major problems in the retinal blood vessel segmentation are a wide variety of vessel width presence and the heterogeneous background of retina. It leads to stroke, cardiovascular disease, diabetes and hypertension [3]. Based on ISNT rule, the neuroretinal rim is the thickest inferior side that are subsequently by superior, temporal and the nasal for a

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normal eye. The five modules of an efficient automatic glaucoma screening system; image preprocessing, segmentation of superpixel, feature extraction of superpixel, classification of superpixel and screening metrics of glaucoma disease, the noises are removed from the images by using filters. There are many approaches to develop a computer vision algorithm based on fundus retinal images for glaucoma identification. We can detect the disease automatically and manually by feature image to achieve a high quality in segmentation. Optic disc segmentation gives better results than the optic cup [4].

Glaucoma diagnosis has an intraocular pressure and vision loss has examined together with a manual evaluation of the Optic Disc (OD) through the ophthalmoscopy. In general, 2D images on the optic disc has classified into two different zones they are central bright zone called the optic cup and a peripheral region called the neuroretinal rim. The optic nerve fibers losses that lead to change in the structure of Optic Disc (OD) that expand the region of cup called as Cupping, [5]. Optic Disc (OD) has millions of converge fibers. The sensitive nerve fibers are damaged while increasing the fluid pressure and fibers are began to die. Glaucoma disease diagnosis on various parameter such as cup edge and diameter, optic disc radius, mean cup depth and rim area got estimated to detect the glaucoma disease, all these calculations are concentrated on Optic Disc (OD) research and the glaucoma diseases aspect only one reflect, they are successfully capturing the Optic disc (OD) hierarchical deep features.

A CDR (Cup-disc ratio) is the significant indicator of glaucoma, which is well-defined as the ratio of the vertical height of the optic cup to the optic disc. The Cup becomes larger on the progresses of the optic nerve cupping. The cup-disc ratio (CDR) that describes the propagation of cup occupied the disc and then authorized by the directory for evaluation of the glaucoma disease. For the normal eye it is discovered to be 0.3 to 0.5. Then the ratio of the CDR got increased. And at the values of CDR is 0.8 that indicated the permanent vision loss [6]. Glaucoma can be detected automatically then it is useful in some situation like mass Screening, this can be utilized according to the analysis of fundus images. The Convolutional Neural networks (CNN) are also used to solve the problems, they can gather the image for the information which can help them to discriminate between the glaucomatic and non-glaucomatic images structure for diagnosis [7]. Initially, the region of interest (ROI) is localized, different set of approach is functional for the detection of Optic disc (OD) and the concentration analysis is based on histogram used for the optic cup segmentation [8].

The automatic process of disease detection is more enabled to the computational method, more efficient in resulting, protective and diagnosis cost is low. They are compared with traditional method, the combination of computation tools and specialists enables the diagnosis with an advanced step of sensitivity and specificity, also in symptomless diseases such as glaucoma [9]. The early diagnosis and method will prevent the permanent blindness. Many efforts can be done on the automatic identification of the glaucoma disease at a preliminary stage.

In this paper detection of a neuro-degenerative disease called glaucoma that affects the optic nerve is explained. The disease can be diagnosed by new methodology of multiscale retinex algorithm is presented with relevant outputs. Related work about the glaucoma disease has explain on section 2, Proposed methodology structure have been described on section 3, Result and discussion part are presented on section 4 and the final part of conclusion has explained on section 5.

II. RELATED WORK

A glaucoma detection based on wavelet algorithm for real-time system is proposed in [10]. Using three different method analysis the wavelet-based statistical and features textural for glaucoma detection is experimented. The high-resolution retinal images requires less than 3s for real-time application. The KNN classifier proposed method was achieved the better accuracy of 96.7%. Both the frequency and spatial information are advantages of capturing wavelet features for glaucoma classification. The glaucoma classification is measured from the approximation sub bands for detection.

The diagnosis of glaucoma method is examined by using the scanning-laser-tomography on optic nerve head [11] presented here. Proposed methodology is based on optic nerve head segmentation and morphological operation based on its validation, active contour model and Hough transform. They calculated the error rate by the estimation of manually and automated segmentation to detect the parameter of shape in optic nerve head to differentiate between normal eye and glaucomatous eye damage. By using this proposed method, the images are classified correctly in 72.3%. This algorithm is automatically used between major and minor optic nerve head with the parameters and they could be segmented effectively even if few anatomical structures cannot be determined in optic nerve head. Also, the proposed the method implemented on the automated segmentation variability of manual outline images from same eye and show variable illumination.

The neurodegeneration of the optic nerve that causes the glaucoma diseases which leads to vision loss. [12] proposed by using three image processing techniques that are used to diagnosis the disease. The used algorithms are multi-thresholding, active contours, region growing segmentation process, these are used to evaluate the accuracy of sensitivity and specificity. These methods are applied on the preprocessed fundus image segmentation in which detection of disease by computing CDR is performed. In this methodology, the region-based segmentation techniques give better result when compared with other two algorithm. The disadvantage is few databases is used then the sensitivity performance is low but this method is easy and simple to implement.

A new novel techniques to classify glaucoma by using cascade correlation neural network (CCNN), proposed by *Devasia, Jacob, and Thomas* in 2019 [10]. This method is used to add the hidden unit's one at a time instead of using predetermined hidden set units until the error got reduced. The mesh pattern used to provide a feature map for optic disc and optic cup segmentation by means of a modified fuzzy C-clustering algorithm is an efficient segmentation technique. Here, they computed the values of parameter of glaucoma assessment such as CDR, and ISNT. The research is to differentiate the glaucoma or non-glaucoma images to examine the rule values with extracted features are using by the CCNN classifier. They overcome the problem of Artificial Neural Network (ANN) used for recognition the pattern but they are complex. In this proposed work, they classify three severity stages as early stage, moderate stage and advanced stage. This have compared with manual interpretations and achieved a better accuracy with objective of detecting the glaucoma at early stage for more accuracy. This work needs to be compared with optimized neural network.

The fuzzy logic and different image processing techniques were used in [13]. Which is tested by using the ophthalmologic real database images of both glaucomatous and normal condition cases. Capturing the fundus images of eye that have an amount of noise so we have to perform noise filtration method (Canny operator) to visualize the contours in the pretreatment phase, this method is used to reduce the processing time. By using Gaussian filters, to improve quality and contours are highlighted by applying a contrast and results are obtained in binary images. This method overcome the disadvantage of using Hough transform that take more computational time and still expensive to provide each ellipse detection. In this proposed method, fuzzy engine offers an accuracy of 96.15% correct fundus images are classify. The different classification techniques such as Support Vector Machine (SVM), Artificial Neural Network (ANN) to spot the accuracy, sensitivity, specificity. Compared to the both techniques, this proposed method is based on feature removing and fuzzy logic for categorizing provide the better accuracy.

The fast and automatic detection of glaucoma disease is introduced by using Bayes classifier and principal component analysis (PCA). The transformation and thresholding are combination of the distance located on the optic disc center. The two spaces are projected on the test images and then the calculation is done between each template and propagation distance. Based on principle component analysis (PCA), locate the OD and detect the glaucoma from retinal images. When the rental image illumination is inhomogeneous, it causes the wrong location of optic disc, then the optic disc becomes enlarge. Then the glaucomatous images and regular images are examined the result frequency for glaucoma detection is 78%, in this method, Eigen space got extracted from images by using PCA method. Finally, the projection and spaces distance between them got measured by Bayesian classifier. This proposed method is faster than other and takes low computation time in every pixel [14].

III. Proposed Method

In proposed system, few steps are needed for detecting glaucoma. The selection of input image, Region of Interest (ROI) detection, preprocessing using luminosity and contrast normalization by multiscale retinex algorithm, k-means clustering is used in blood vessel extraction and optic disc segmentation by edge detection using canny and Sobel operator. Figure 1, shows the proposed model with its various steps included.

A. Preprocessing

Image preprocessing is done before image processing. The damaged image is cut off from the input image to provide better performance in the proposed model. Preprocessing the image includes removal of background noise with low frequency, screening portion of image and removal of replication under several illumination condition. The preprocessing method enhance the image preceding to computational processing. It corrects the error of the input image and enhance the reliability of optical assessment significantly.

Region of Interest (ROI)

The sub-image of the input image is mentioned as region of interest (ROI). ROI mention the circumstance of the image which frequently contain collections of objects in the basis of region. In an image processing system, ROI

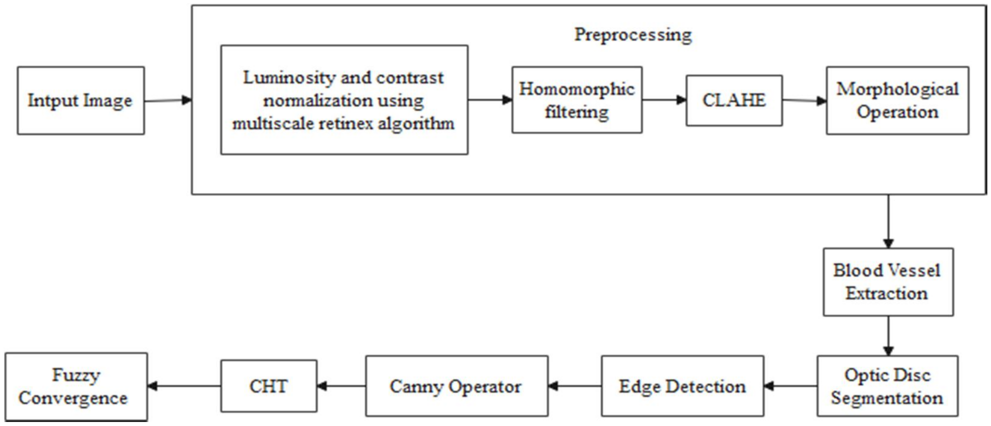

Figure 1. Block diagram of proposed System

can able to use specific image processing methods for selected region. In the proposed system, the retinal image is circular and fundus image is rectangular. The mask of retinal region is used to select the region of interest from fundus image. The mask of retinal region is segmented for general framework of the proposed system.

Luminosity and Contrast Normalization

The eye produce image with contrast variability and high luminosity due to its spherical surface and the uneven illumination at acquisition stage. Without pre-processing, the automatic analysis of retinal image is not possible in which image contrast and luminosity are normalized in this stage. The retinex algorithm is utilized to enhance the retinal image. The retinal theory describes the visual system of the human which perceives the color image of the object in changing illumination condition. The frequency spectrum of image will distribute at low frequencies when the illumination changes gradually. The normalized image is computed by approximating the illumination and subtracting the normalized image from the original image.

The multiscale retinex in human perception is a color image enhancement method which provide dynamic range intensity and constancy. The light rendition and the color of the image is effectively achieved using multiscale retinex along dynamic range compression. The multiscale retinex algorithm is mathematically represented as

$$MSR = \sum_{m=1}^{M} \alpha_m P_{mi} \text{ M} \tag{1}$$

where M are number of scales, P_{mi} is the ith component of M scale

The illumination correction is performed using homomorphic filter technique. The homomorphic filtering is proposed for illumination-reflectance model which can be utilized to enhance the frequency-domain method to develop the image appearance by contrast enhancement and gray-level range compression simultaneously. Each value of pixel f (a, b) can be expressed as the product of reflectance component r (a, b) and illumination component i (a, b), which is expressed as

$$f(a,b) = i(a,b)r(a,b) \tag{2}$$

The independent component is separated to facilitate processing

$$z(a,b) = \ln\ f(a,b) = \ln(i(a,b)r(a,b))$$

$$z(a,b) = \ln i(a,b) + \ln r(a,b)$$

Processing $z(a,b)$ using a homomorphic filter function h,

$$s(a,b) = h * z(a,b) = h * \ln i(a,b) + h * \ln r(a,b) \tag{3}$$

According to convolution theorem

$$S(c,d) = H(c,d)Z(c,d) = H(c,d)F_i(c,d) + H(c,d)F_r(c,d) \tag{4}$$

Where $S(c,d), H(c,d), Z(c,d)$ are the transform of $s(a,b), h(a,b), z(a,b)$

Inverse transform of $S(c,d)$ to compute $s(a,b)$ is given as

$$s(c,d) = \Im^{-1}\{S(c,d)\} \tag{5}$$

$$s(c,d) = \Im^{-1}\{H(c,d)F_i(c,d)\} + \Im^{-1}\{H(c,d)F_r(c,d) \tag{6}$$

Where $\Im^{-1}$ is an inverse operator of the homomorphic filter

$$i'(a,b) = \Im^{-1}\{H(c,d)F_I(c,d)\}$$

$$r'(a,b) = \Im^{-1}\{H(c,d)F_r(c,d)$$

Then the inverse transform of homomorphic filter is

$$s(a,b) = i'(a,b) + r'(a,b) \quad (7)$$

The enhance image after filtering using homomorphic filter is $g(a,b)$ which is represented as

$$g(a,b) = e^{s(a,b)} = e^{i'(a,b)}e^{r'(a,b)} = i_0(a,b)r_0(a,b) \quad (8)$$

where $i_0(a,b) = e^{i'(a,b)}$ and $r_0 = e^{r'(a,b)}$ are the illumination and reflectance component of the fundus image after filtering.

The contrast adaptive histogram equalization is a variant of adaptive histogram equalization that is utilized to enhance the contrast in image by limiting the lightness of the image. It is a method which overcome the global technique limitation by performing local contrast enhancement.

CLAHE

Contrast Limited Adaptive Histogram Equalization (CLAHE) is a technique, that enhance the low contrast problem in retinal image. The transformation function of CLAHE is derived from the procedure of contrast limited to each neighbor pixel. CLAHE mainly operates by limiting the contrast enhancement, that is performed by histogram equalization and result in enhancement of noise. The noise is prominent by improving contrast limitation in retinal image. The contrast enhancement is a slope function which related the image intensity of input and output image.

Morphological Operation

Morphological operation is utilized to remove the blood vessel within the optic disc and intensity around the disc is smoothened. It is mainly used to remove the imperfection of image during segmentation.

B. Blood Vessel Extraction

The detection of changes in the structure of retinal system is a repetitive and critical task in fundus color image. The blood vessel segmentation of retinal fundus image is to improve image quality which is achieved by separating the retinal image in to three different colors. The segmentation of image using clustering method is done using k-means clustering. The pseudo code for k-means clustering algorithm is given as

Step 1: Determining number of clusters, c and initial centroid μ

Step 2: Membership of each cluster is determined using the Euclidean distance.

$$d_j = \min_i \|x_i - \mu_j\| \quad (9)$$

Step 3: New centroid calculation

$$\mu_j = \frac{1}{n}\sum_{i=1}^{m} x_i \quad (10)$$

Step 4: step 2 and 3 is repeated

$$\sum_{i=1}^{m}\sum_{i=1}^{n}\|x_i - \mu_j\|^2 \quad (11)$$

The generated cluster center using k-means algorithm is further used in threshold processing. It can be further processed using the Gabor and Gaussian filter.

C. Optic Disc Segmentation

The optic disc segmentation can be obtained by predicting the boundary of the optic disc in the retinal image using morphological algorithms. The fundus image consists of red, blue and green color channel which is interconnected with blood vessel. The red channel has high difference among the non-optic and optic disc when compared with green and blue channel. The morphological operation is processed to remove blood vessel and the edge of disc is sharped. HSV color is transformed from RBG. The human eye is easily defined using RBG color. More contrast among the disc area and non-disc area is taken using value channel and the intensity value is adjusted by performing equalization. The preprocessing is facilitated to separate the region of interest using the localization method. The image is segmented into several objects using multilevel image segmentation process to predict the object with high brightness. The edge detection is inclined by the blood vessel. The optic disc edge algorithms are developed to optimize the edge of the optic disc and improve the performance accuracy. The edge detection is obtained using canny and Sobel edge detection method.

Canny Edge Detection

The canny edge detection is a multi-stage algorithm which is utilized in input image. The canny edge operator is sensitive and take minute gradient of the retinal image and introduce unwanted noise, which is removed using filtering. It is extensively utilized in the computer vision system as it is used in image processing due to various advantages. The filter response is given as

$$I_E = \int_{-x}^{x} E(-y)\, f(y)\, dy \qquad (12)$$

where E(y) id edge and f(y) is filter response

RMS response is given as

$$I_a = \sqrt{a_0^2 \int_{-x}^{x} f^2(y)\, dy} \qquad (13)$$

where a_0^2 is the RMS value

The output signal to noise ratio is given as

$$SNR = \frac{\int_{-x}^{x} E(-y)\, f(y)\, dy}{\sqrt{a_0^2 \int_{-x}^{x} f^2(y)\, dy}} \qquad (14)$$

Localization of image is given as

$$Localization = \frac{\int_{-x}^{x} E'(-y)\, f'(y)\, dy}{a_0 \sqrt{\int_{-x}^{x} f'^2(y)\, dy}} \qquad (15)$$

The optic disc segmentation is performed using the canny edge detection method in which the localization of the image of interest is obtained from fundus image of retina.

Sobel Edge Detection

The Sobel operator is implemented for both hardware and software detection of fundus image. The gradient of the image is detected for segmenting the image. The gradient component is represented as

$$\Delta x = \frac{\delta f(x, y)}{\phi m}$$

$$\Delta y = \frac{\delta f(x, y)}{\phi m}$$

The direction and magnitude of gradient of the image is given as

$$G = \sqrt{(\Delta x)^2 + (\Delta y)^2}$$

$$\phi = \tan^{-1} \frac{\Delta x}{\Delta y}$$

Circular Hough Transform

The Circular Hough Transform is used to determine the circular pattern within the retinal image. It basically works on the logic of geometric shape of edges. The circular Hough Transform utilized to identify the circles and geometric shape of the retinal image. The transformation of point in cartesian space defined by the shape of the retinal image. The point on the circle is defined as,

$$c^2 = (x-a)^2 + (y-b)^2 \quad (16)$$

Where (a, b) represent the center of circle. The three-dimensional parameter space is denoted as (a, b, c), known as circular Hough space.

The procedure for circle detection is given as follows

1. Obtain the edge of the retinal image
2. Set the value of a and b
3. Solve equation (16) for the value of c
4. The accumulator is updated as (a, b, c)
5. Update the value of a and b with the range of interest.

Fuzzy Convergence

Fuzzy convergence is used to identify the position of the optical nerve image. The issues in finding convergence of the blood vessel may be modeled as the intersection problem. Mostly voting based method is used in fuzzy convergence. Each pixel produces an image which proportionate to strength the convergence.

IV. RESULT AND DISCUSSION

The optic disc segmentation is demonstrated based on the fundus retinal image. The edge detection method such as canny and Sobel edge detection methodology is utilized in this proposed system. The obtained result of segmented retinal image is given as follows.

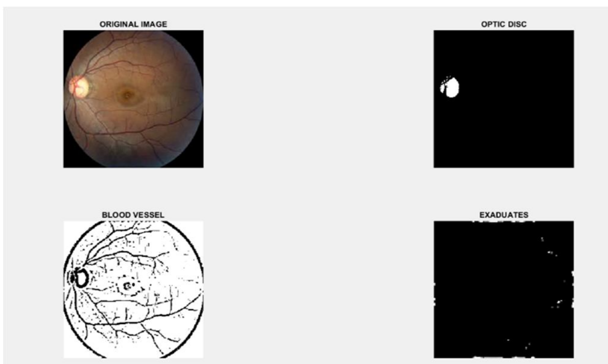

Figure 2. Processed Fundus retina image

The figure 2. Illustrated above is the original fundus image of the retina. The blood vessels have low brightness when compared to the retina and the intensity are darker than other retinal pixel.

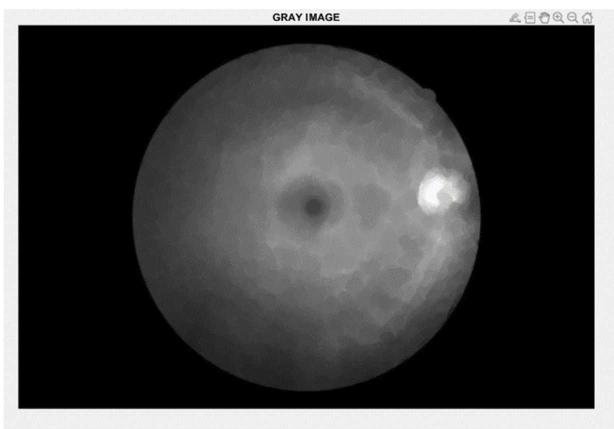

Figure 3. Gray image of the retinal image

The retinal image for glaucoma detection is presented which is utilized for generating the color image of the retina. The gray image is predicted using the morphological operator, the luminance of each pixel is obtained by removing all the color image.

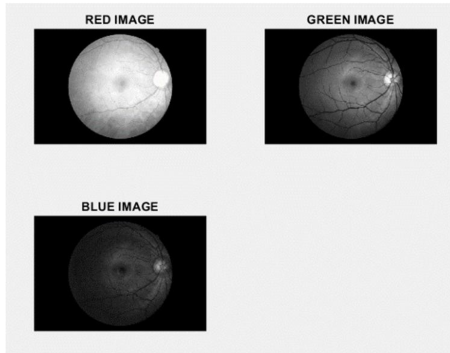

Figure 4. Red, Blue and Green channel of retina image

The color images of the retina are composed of red blue and green channel. The luminosity of the red color image has more intensity and the pixel of image in blue color have low luminosity and have low resolution in image.

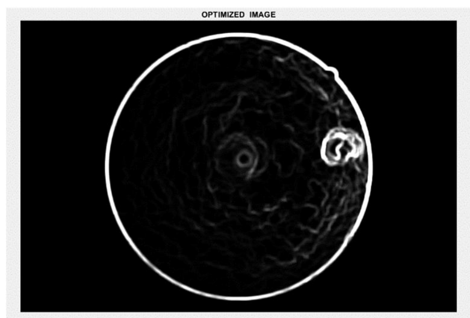

Figure 5. Optimized Image

The above figure provides the optimized image of fundus retinal image for glaucoma detection. The optimization is performed for segmenting the optic disc of the retina image for detecting glaucoma in eye.

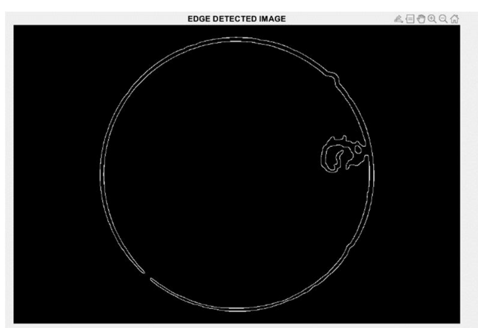

Figure 6. Edge detection

The optic disc is segmented with minimum edge image having high brightness and it is utilized for classification purpose in detecting the glaucoma disease.

A. Discussion

The performance of segmentation is examined in the figure 6. The combination of edge detection method provide improvement in the segmentation result. The adaptive morphological approach is utilized to enhance the optic disc segmentation. The morphological approach is designed to get the gray image to increase the luminosity of the image and the red, blue and green image of the retinal eye is obtained for segmenting the optic disc of the retinal image with gray image. The edge detection method combined with morphological approach provide better segmentation for glaucoma detection.

V. Performance Metrices

TABLE I PERFORMANCE METRICES OBTAINED WITH PROPOSED METHODOLOGY

PSNR	+ 4.35 dB
MSE	0.3670
Normalized cross-correlation	0.1271
Average Difference	0.3121
Structural Content	5.0583
Maximum Difference	1
Normalized absolute error	0.9436

VI. Conclusion

Segmentation of optic disc in glaucoma detection using edge detection algorithm performed in this method. Using the edge detection, the optic disc is segmented and disease in the observed and the canny operator filters the noise in the Fundus image. The retinal image is taken and the segment classification is done. In the existing region growing segmentation process and morphological operation method were used to detect the optic nerve head but it does not produce the clear output in segmentation process. The edge detection produces the clear out and the image is segmented. To optimize the noise and the error in the image various type of filter is used and hence grey image of the retina is obtained. By using this image, the effect in the optic nerve head is detected. Thus, the segmentation is done by using the edge detection method without any effect of noise with absolute performance as compared to traditional canny edge detection method.

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