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Automated Identification of Diabetic Retinopathy Stages in Digital Fundus Image using CDR and Micro aneurysms

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Abstract: ***Diabetic retinopathy (DR) and glaucoma are the commonest complications of diabetes and is one of the leading causes of blindness. Early detection of occurrence of DR can greatly help in effective treatments. Very effective treatments are available and are optimally used when retinopathy is detected early. For this reason screening programs for early detection of retinopathy is essential part. The retinal fundus photographs are the main resources for screening of DR. In this work we tried to locate the eye optic disc and optic cup using k-means algorithm, morphological operation and watershed transform. Segmented optic disc and cup are then used to compute the cup to disc ratio for DR screening, for grading the disease we use micro aneurysms. Micro aneurysms are the clinical sign of DR they appear small red dots on retinal fundus images, their detection can be used to grade the DR in different stages.***

Keywords: Diabetic retinopathy (DR), Cup to disc ratio (CDR), micro aneurysms (MA).

1. Introduction

Diabetic retinopathy (DR) is an eye disease that can lead to partial or even complete loss of visual capacity, if left undiagnosed at the initial stage. It occurs when diabetes damages the tiny blood vessels inside the retina. In the early stage DR will not affect the sight, but the changes get worse the sight will be affected. The disease progresses without any noticeable symptoms until the damage has occurred. It usually affects up to 80%of all patients who have had diabetes for 10 years or more [7]. The normal retinal image has clear blood vessels and optic disc, the bright circular area in the eye. It carries neurons from the eye to the brain. Macula is the dark spot in the eye, which helps in detailed central vision. DR may cause several abnormalities in the retina, the tiny blood vessels leak blood and fluid on the retina and form features such as micro aneurysms(MAs),hemorrhages, hard exudates, cotton wool spots or venous loops is as shown in fig1.

Diabetic retinopathy has four stages:

1. Mild Non Proliferative Retinopathy: Micro aneurysms develop, which are small swelling in the tiny blood vessels of the retina**.**
2. Moderate Non Proliferative Retinopathy: As disease progresses, some blood vessels that nourish the retina, and supply blood to the retina can leak fluid or become blocked. At this stage many MAs, hemorrhages, hard exudates and cotton wool spots may be seen.
3. Severe Non Proliferative Retinopathy: Many more blood vessels are blocked; several affected area of the retina lack of oxygen will occur and do not get a proper blood supply. This area signal to be sent to trigger the growth of new blood vessels for nourishing the retina.
4. Proliferative Retinopathy: At this advanced stage signal sent by the retina cause the growth of new blood vessels, these new blood vessels are abnormal therefore leakage of blood vessels will occur which may result in severe vision loss and even blindness.

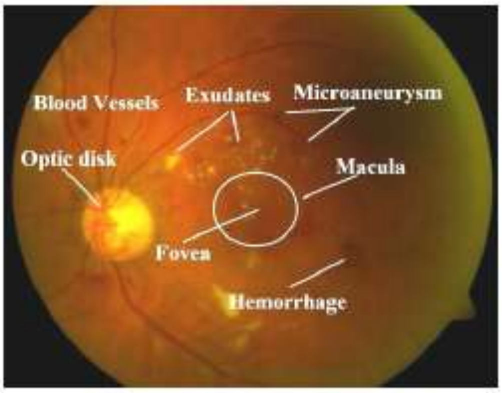


Figure 1: Retinal main regions and DR related pathologies

2. Methodology

This paper presents a computer aided system for an automated detection of disease at the earliest for effective treatment through the usage of retinal color fundus photographs. In this work the optic disc and cup are segmented for calculation of CDR which helps in determination of DR. the number of micro aneurysms present in the diseased eye is used to indicate the severity of diseases, their detection can be used to grade the DR into different stages such as mild, moderate, and severe. A section of optic nerve that is apparent in the retinal fundus image is called Optic Disc (OD) or optic nerve head (ONH) [8]. OD is the brightest feature, orange pink in color with a pale center known as optic Cup. Blood vessels and optic nerve fibers are radiated out of the OD. The neuro retinal rim consists of nerve fibers and optic cup does not contain any nerve fibers. The normal optic disc consists of approximately 1.5 million nerve fibers but in DR there is no proper blood supply because of damaged blood vessels in retina, and consequently there is a lack of nourishment in the retina resulting in death of the nerve fibers. Thus, thinning of the neuroretinal rim along with the enlargement of cup (cupping) takes place (fig2). Evaluation of optic Cup-to-Disc Ratio (CDR) will help for appraisal of DR [1]. For normal eye, CDR valve is found to be 0.1 to 0.3. As the optic nerve degenerates, the CDR ratio increases. Calculation of CDR helps in classifying the images.

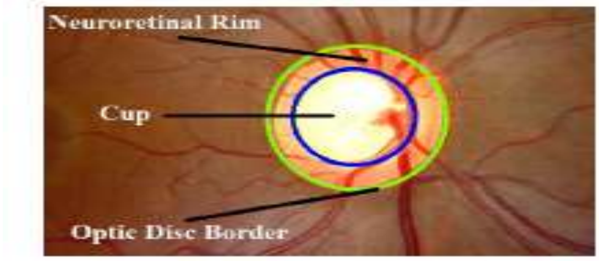


Figure 2: Optic Disc structure

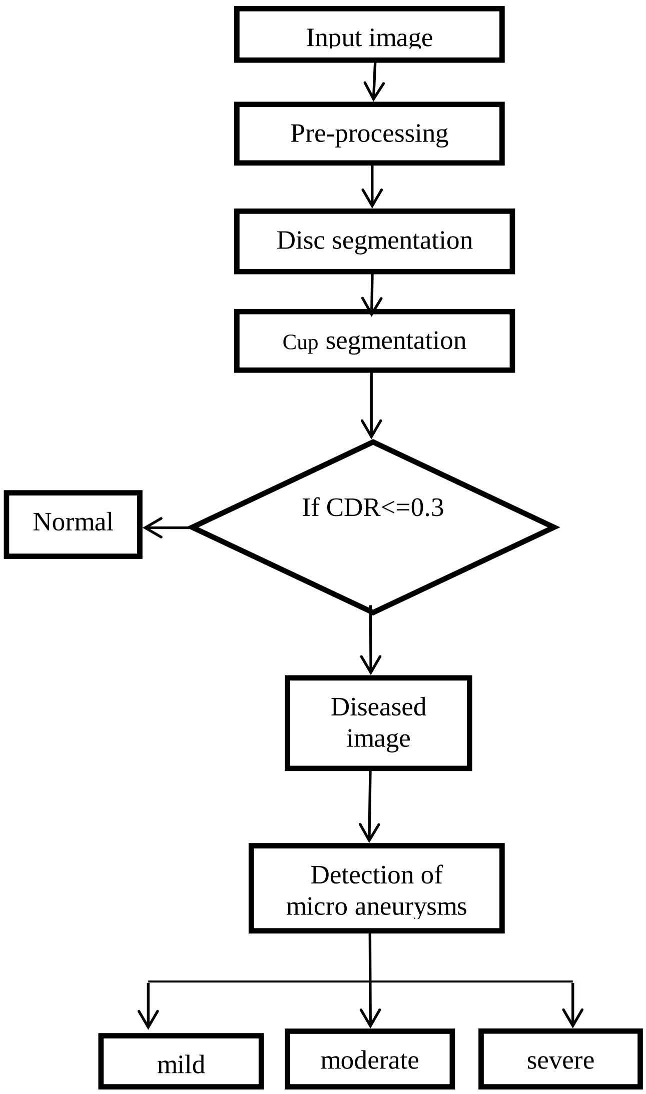
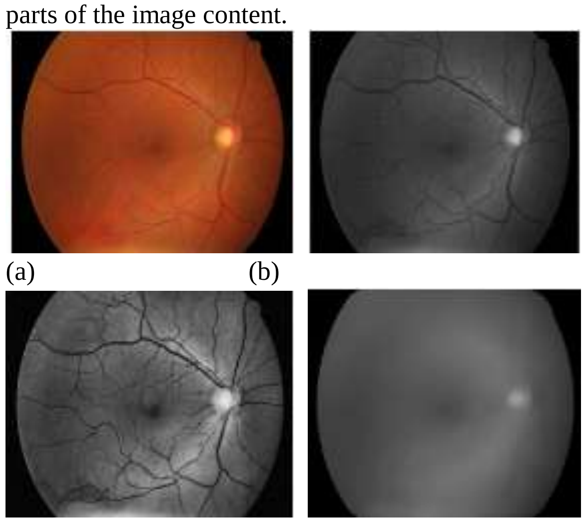


Figure3: Flowchart of overall process

2.1. Preprocessing

The aim of preprocessing is to attenuate the noise, to improve the contrast and to correct the non-uniform illumination. The retinal image is taken in the RGB form by fundus camera. The preprocessing algorithm includes the extraction of the green band from original RGB retinal images (fig 4(b)). The green channel provides the best vessel-background contrast of the RGB representation, while the red channel is the brightest color channel and has low contrast, and the blue one offers poor dynamic range. Hence green channel is used for further processing. Normalization and contrast enhancement is performed to improve the image quality. Adaptive histogram equalization is applies for contrast enhancement as shown in fig4(c). After contrast enhancement apply median filter for noise removal (fig 4(d)). It's a nonlinear digital filtering technique to reducing image noise without removing significant parts of the image content.



(a) (b)

(c) (d)

Figure 4: a) Input image b) Green channel of image c) Adaptive histogram d) Median filtered image

2.2 segmentation of optic disc

2.2.1 k-means clustering

K-means algorithm [3] plays a vital role in localization of optic disc. A K-means is an unsupervised clustering algorithm that classifies the input data point into multiple classes based on the inherent distance from each other. The algorithm assumes that the data features from a vector space and tries to find a natural clustering in them. The points are clustered around centroids $\mu_i \; \forall_i = 1 \ldots k$ which are obtained by minimizing the objective

$$V = \sum_{i=1}^{k} \sum_{x_j \in s_i} (x_j - \mu_i)^2 \qquad (1)$$

Where there are k clusters S_i, i=1 2…...k and μ_i is the centroid or mean point of all the points $x_j \in S_i$

Algorithms as follows,

1. Place k-point of the object, it represent an initial group of centroid.
2. Assign each object to the group that is closest to the centroid.
3. Recalculate the position of the centroid, when all objects have been assigned.

4. Repeat step 2 and 3 until the centroid no more changes take place.

Before applying k-means algorithm first we need to convert color retinal image to gray scale later we apply above algorithm than we get the result of localization of optic disc in retinal image is as shown in figure 5.

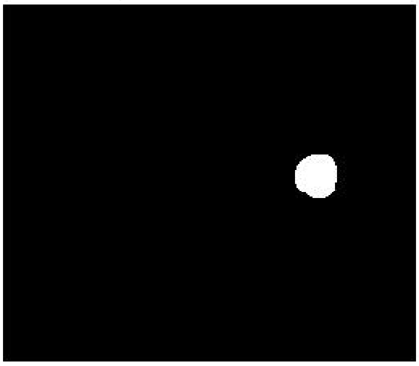


Figure 5: Segmented optic disc

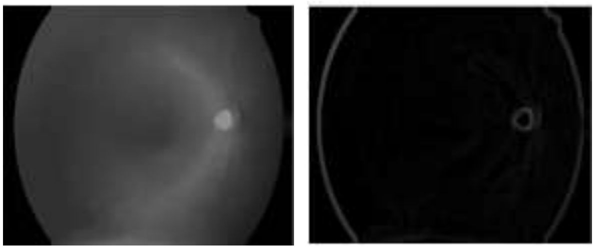
2.3 segmentation of optic cup

Several processes are involved in the cup segmentation. After preprocessing the shape of the optic disc is determined by reconstruction by dilation process. Watershed transform [6] is applied for segmentation of optic cup.

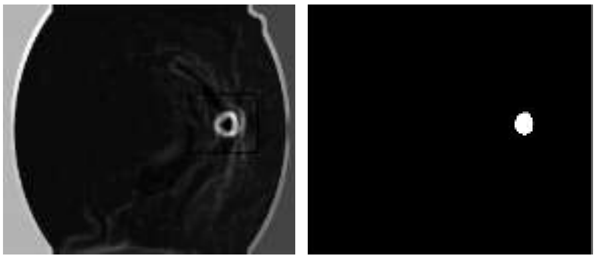
2.3.1 Marker-controlled watershed transformation

Watershed transform is a segmentation technique for gray scale images. This algorithm is a powerful segmentation tool whenever the minimum of the image represents the objects of interest and the maxima are the separation boundaries between objects. Due to this fact, input image of this method is usually a gradient image as shown in fig 6(b). The gradient magnitude image has high pixel valves along object edges, and low pixel valves everywhere else. In morphological methodology, the gradient of an image is obtained as the point wise difference between a unitary dilation and unitary erosion [6].

Watershed transform to a gradient image can result in over segmentation due to noise and other local irregularities of the gradient. To avoid this markers are used, markers is a connected component belonging to an image. The segmentation method uses markers to build a contour of cup region. Both internal and external markers are used. The internal marker is drawn based on centroid of an image. The external marker will be a rectangle centered on the centroid of the image, in this method an internal and external markers are defined and it is imposed on the image as shown in fig6(c). Then the logical OR of both internal and external markers is applied into the optic disc region. After logical OR operation watershed transformation is applied to get a cup region shown in fig 6(d).



(a) (b)



(b) (d)

Figure 6: a) Reconstruction by dilation b) Morphological gradient c) Imposing the markers on gradient image d) Segmented optic cup.

2.4 Cup to disc ratio

After obtaining the disc and cup region, we have to count the number of white pixels in the segmented disc and cup region for calculating CDR. CDR is an important indicator for glaucoma as well as diabetic retinopathy screening computed as

$$CDR=\frac{VCD}{VDD} \quad (2)$$

Where VCD is vertical cup diameter and VDD vertical disc diameter. The normal CDR is 0.3. A large CDR may imply DR.

2.5 Micro aneurysms detection

Detection of micro aneurysms is the important factor that is used to identify the severity of the diabetic retinopathy. Hence identifying the number of micro aneurysms in human retinal image is the major work to identify the stage of the disease. Finding out the stages is useful for further treatment.

After preprocessing the retinal image micro aneurysms are segmented by separating them from the blood vessels. Vessels and MAs are binarized by thresholding. Micro aneurysms appear as dark red dots of 10 to 100 microns diameter, circular in shape and are disconnected from the vessels. Micro aneurysms can be extracted based on shape and size. Area of the blood vessels will be large thus can be differentiated from MAs based on area. Objects having the area greater than threshold valves are eliminated, after eliminating vessels resulting image may include micro aneurysms, noise and other particles. Object having greater than or less than MAs considered to be noise that should be removed by two threshold values that are decided by experimentation.

As MAs are circular in shape, they can be identified from noise which is irregular in shape. Finally, MAs are detected based on perimeter and circularity [4], [5]. Canny edge detector is performed on resulting image. Each object area and perimeter is calculated and these results are used to form a simple metric indicating the circularity of the object. The perimeter is calculated by finding the length of the boundary pixels of the candidate.

$$\text{Delta} = \text{diff (boundary).\^{}2} \quad (3)$$

$$\text{Perimeter=sum} \left(\sqrt{sum(delta,2)} \right) \quad (4)$$

$$\text{Metric}=\frac{4*\Pi*area}{perimeter^{2}} \quad (5)$$

This metrics is equal to one for a circle and it is less than one for any other shape. The discrimination process can be controlled by setting an appropriate threshold α.
α={0.92,0.94,0.95,0.96,0.97,0.98,0.99,1.00,1.01,1.02}
Metric close to one indicates the micro aneurysms, Shown in the fig7.

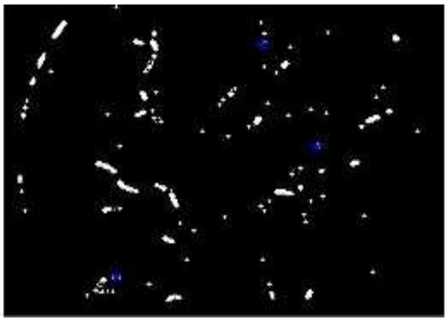


Figure7: Detected micro aneurysms

3. Conclusion

An automated CDR measurement system is a reliable and an efficient method for the diagnosis of glaucoma or diabetic retinopathy. The diagnosis can be done through measurement of CDR, defined as the ratio of the vertical height of the optic cup to the vertical height of the optic disc. The normal cup to disc ratio range is from 0.1 to 0.3. If the CDR exceeds 0.3 then it indicates the abnormal condition that is the presence of DR. Based on this experimental results shows the input image is considered as retinopathy affected fundus.
The number of micro aneurysms is the important parameter used to identify the severity of the diabetic retinopathy. Hence the detection of micro aneurysms in human retinal image is the major work to identify the stages of the disease. The algorithm shows a 94% of accuracy over a database of 50 images.

Table 1: Grading of Diabetic Retinopathy

DR stage	
Grade 0 (No DR)	MA=0
Grade1(mild)	1<MA<5
Grade2(moderate)	5<MA<15
Grade3(severe)	MA>15

MA=Micro aneurysms

4. Acknowledgment

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