Analysis of the Severity of Hypertensive Retinopathy Using Fuzzy Logic

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Abstract. Eye, an organ associated with vision in man is housed in socket of bone called orbit and is protected from the external air by the eyelids. Hypertensive retinopathy is a one of the leading cause of blindness amongst the working class in the world. The retina is one of the "target organs" that are damaged by sustained hypertension. Subjected to excessively high blood pressure over prolonged time, the small blood vessels that involve the eye are damaged, thickening, bulging and leaking. Early detection can potentially reduce the risk of blindness. An automatic method to detect thickening, bulging and leaking from low contrast digital images of retinopathy patients is developed. Images undergo preprocessing for the removal of noise. Segmentation stage clusters the image into two distinct classes by the use of fuzzy c-means algorithm. This method has been tested using 50 images and the performance is evaluated. The results are encouraging and satisfactory and this method is to be validated by testing 200 samples.

Keywords: hypertensive retinopathy, hypertension, retinopathy, segmentation.

1 Introduction

Hypertensive retinopathy is the term used to describe the changes to the retinal vascular system that happen due to high blood pressure [1]. It is believed that retinal assessment may be a valuable tool in gathering information regarding systemic micro vascular injury [2].

Today, many guidelines define hypertensive retinopathy as target organ injury. Although the Joint National Committee (JNC) 7 report published in 2003 defines all retinopathy stages as target organ injury, World Health Organization (WHO) / International Society of Hypertension (ISH) 2003, British Hypertension Society (BHS) IV 2004, European Society of Hypertension (ESH)-European Society of Cardiology (ESC) 2003 guidelines suggest that only grades 3 and 4 should be accepted as target organ injury [2]. The Seventh Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure and the V Brazilian Guidelines on Hypertension list hypertensive retinopathy as a marker of target organ damage. Therefore, it is a criterion for prescription of treatment [3], [4]. However, the most common

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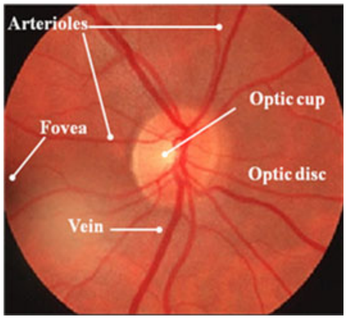
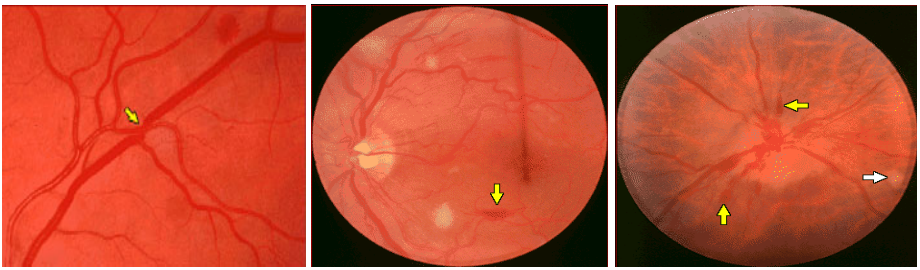


Fig. 1. Normal Ocular Fundus



(a) (b) (c)

Fig. 2. (a) Grade 2, (b) Grade 3 & (c) Grade 4

grades of retinopathy are 1 and 2 [5].Therefore, it is important to understand the clinical significance of the retinal changes in these grades.

By 1939, Keith et al. had classified patients with hypertensive retinopathy into 4 groups. They described the course and prognosis of these patients with hypertension according to the degree of retinopathy. Group I was restricted to minimal constriction of the retinal arterioles with some tortuosity in mildly hypertensive patients. Group II included arteriovenous nipping, while group III included hemorrhaging and exudates. Group IV included papilledema [6],[7],[8]. Group I and II are compensated hypertensive retinopathy and Group III and IV are accelerated hypertensive retinopathy. MHT is a clinical syndrome characterized by severe systolic and diastolic hypertension, usually appearing progressively over a period of several weeks to several months; it is often associated with significant and progressive deterioration in cardiac or renal function, and there is evidence of encephalopathy [9]. The World Health Organization (WHO) criteria are probably the most useful for MHT; it now differentiates hypertensive retinopathy on the basis of 2 grades of changes in the fundus, fundus hypertonicus and fundus hypertonicus malignus [10]. Patients diagnosed as having malignant hypertension have severe hypertension with bilateral retinal hemorrhages and exudates. Papilledema, unless florid, is an unreliable physical sign and was of no additional prognostic importance in patients treated for hypertension who already had bilateral hemorrhaging and exudates [11] Diastolic blood pressure is usually greater than 130 mmHg, but there is no absolute level above which MHT always develops and below which it never occurs [12].

Table 1. Range of BP for different stages of Hypertensive Retinopathy

CATEGORY	SYSTOLIC BP (mmHg)	DIASTOLIC BP (mmHg)
NORMAL	<130	<85
HIGH NORMAL	130-139	85-89
STAGE 1 (MILD)	140-159	90-99
STAGE 2 (MOD.)	160-179	100-109
STAGE 3 (SEVERE)	180-209	110-119
STAGE 4(V. SEVERE)	>210	>120

Table 2. Stages of Hypertensive Retinopathy and its severity

	HEMORRHAGE	*EXUDATE*	*DISC EDEMA*
GRADE 0	-	-	-
GRADE 1	-	-	-
GRADE 2	-	-	-
GRADE 3	-	+	-
GRADE 4	-	+	+

Fuzzy c-means (FCM) clustering [13,14,15] is an unsupervised method that has been successfully applied to feature analysis, clustering, and classifier designs in fields such as astronomy, geology, medical imaging, target recognition, and image segmentation. An image can be represented in various feature spaces, and the FCM algorithm classifies the image by grouping similar data points in the feature space into clusters [16]. This clustering is achieved by iteratively minimizing a cost function that is dependent on the distance of the pixels to the cluster centers in the feature domain.

2 Methodology

Hypertensive retinopathy images of different grades of severity were obtained and were given as input to Fuzzy C Means (FCM) to undergo series of stages for highlighting the affected region in the image.

The images were of very high quality and there was no requirement to make them noise free using filters. FCM are used here to isolate the optic disk and exudates region from the input image, it converts the gray level image to a binary image. The algorithm assumes that the image to be threshold will contain two classes of pixels then calculates the optimum threshold separating those two classes so that their combined spread is minimal. The FCM method is better than the Otsu method.

Initially, the segmentation of optic disk was performed to avoid its interference during diagnosis by doctors for severity. The affected regions are segmented from the original image and are superimposed on the optic disk and nerve removed processed image. The affected regions are highlighted by setting pixel value to zero. Finally in the superimposed image of red and yellow colour the affected regions are differentiated by highlighting them with green colour.

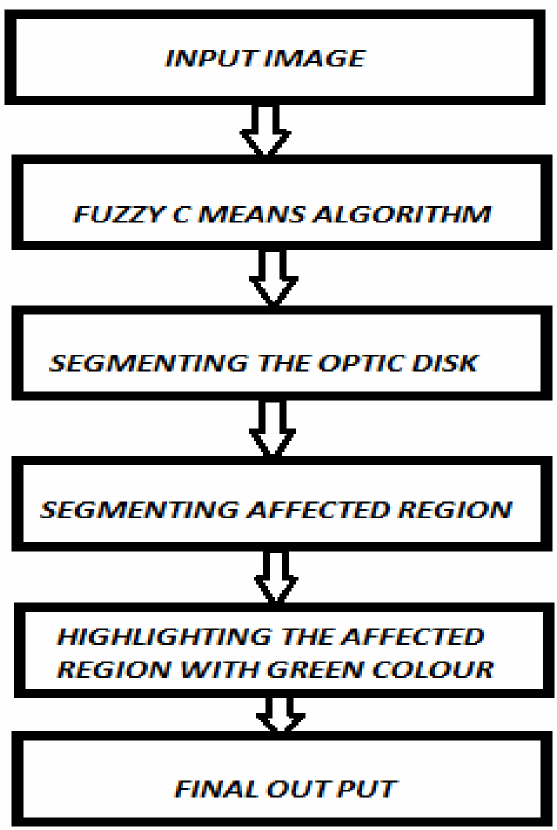


Fig. 3. Block diagram showing each stage of Image Processing

2.1 Program Code

```
clear;
close all;
im=imread('E3.jpg');
fim=mat2gray(im);
level=graythresh(fim);
bwfim=im2bw(fim,level);
[bwfim0,level0]=fcmthresh(fim,0);
[bwfim1,level1]=fcmthresh(fim,1);
subplot(2,2,1);
imshow(fim);title('Original');
subplot(2,2,2);
imshow(bwfim);title(sprintf('Otsu,level=%f',level));
subplot(2,2,3);
imshow(bwfim0);title(sprintf('FCM0,level=%f',level0));
subplot(2,2,4);
imshow(bwfim1);title(sprintf('FCM1,level=%f',level1));
close all;
clc;
 [filename,pathname]=uigetfile('*','Select an image to
segment the pathology');
if(filename==0)
    return;
end
f1_ori=imread(strcat(pathname,filename));
f1_size=imresize(f1_ori,[256 256]);
f1_gray=im2double(rgb2gray(f1_size));
f1_green=f1_size(:,:,2);
f1_green=im2double(f1_green);
se1=strel('octagon',6);
f1_close=imclose(f1_green,se1);
f1_pad=padarray(f1_close,[5 5]);
f1_mean=f1_pad;
f1_var=f1_pad;
[r c]=size(f1_pad);
for i=6:r-5
    for j=6:c-5
        w=f1_pad(i-5:i+5,j-5:j+5);
        local_mean=mean2(w);
        local_std=std2(w(:));
        local_var=local_std^.2;
        f1_mean(i,j)=local_mean;
        f1_var(i,j)=local_var;
        f1_std(i,j)=local_std;
    end
end
```

```
f1_mean=f1_mean(6:r-5,6:c-5);
f1_var=f1_var(6:r-5,6:c-5);
f1_std=  f1_std(6:r-5,6:c-5);
f1_varmax=max(f1_var(:));
f1_thresh=autothreshold(f1_green);
figure,imshow(f1_thresh),title('thresholded image');
[f1_label n]=bwlabel(f1_thresh);
STATS = regionprops(f1_label,'area');
removed=0;
aA=[STATS.Area];
for j=1:n
    bw= aA(j);
    if(bw<1) ||(bw>1000)
    f1_label(f1_label==j)=0;
    removed = removed + 1;
    end
end
n=n-removed;
[row col]=size(f1_label);
for i=1:row
    for j=1:col
        if (f1_label(i,j)~=0)
            f1_label(i,j)=1;
        end
    end
end
```

3 Results

The result obtained using fuzzy logic for the moderate and mild hypertensive retinopathy images, was satisfactory and the output was clear, but for highly affected or worst

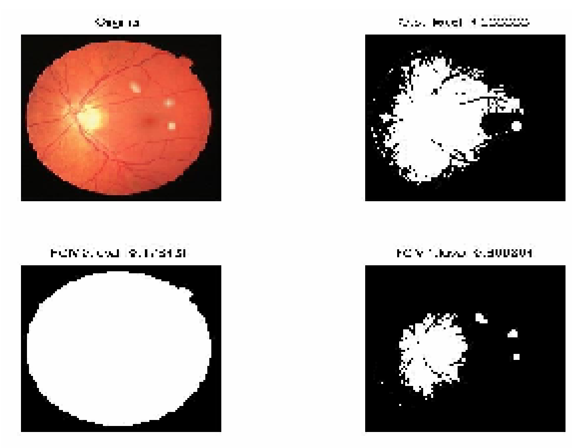


Fig. 4. FCM output

affected hypertensive retinopathy patient images they were not clearly segmented. This problem was overcome by doing other normal segmentation method for isolating the optic disk and exudates region from the severely or worst affected images of hypertensive retinopathy patients. This tool can be used by doctors for evaluation. The stage wise output images are as shown below for a particular input image.

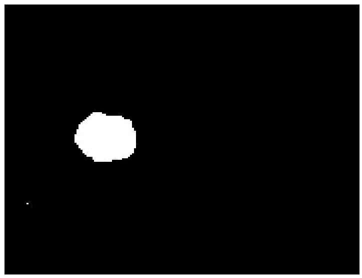


Fig. 5. Segmented optic disk

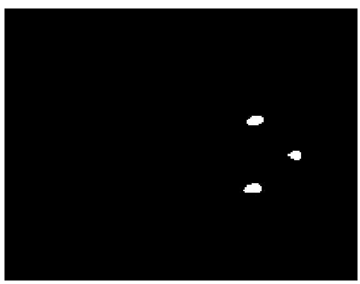


Fig. 6. Segmented exudates region

Fig. 7. Setting the affected region to zero for highlighting

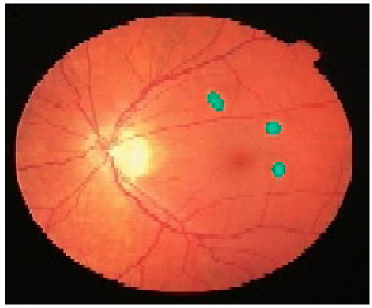


Fig. 8. Final output

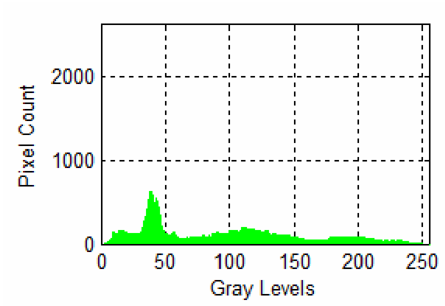


Fig. 9. Graphical display of severity

4 Conclusion

In this paper we have presented a new effective and simple method to analysis the severity of the hypertensive retinopathy. In the last section we are yet to calculate the segmented region which is replaced by green colour, so by calculating the green colour pixel values of the image we can calculate the severity. We are working with the mild, moderate and severely affected images to calculate the pixel. Still our research is going on with hundreds of images to calculate the pixels, so that based on the pixel values we can categorize the stages of hypertensive retinopathy. This newly developed method can be of great benefit to ophthalmologist in their severity analysis for hypertensive retinopathy patients.

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