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A comparative Study on Optic Disc Localization with Application to Diabetic Retinopathy in Fundus Images

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ABSTRACT
Diabetic retinopathy (DR) is one of the leading causes of blindness in the world among patients suffering from diabetes. It is an ocular disease and progressive by nature. DR is characterized by pathologies, namely, micro aneurysms, hard exudates, soft exudates, hemorrhages, etc. The presence of exudates is the prominent sign of non-proliferative DR. To successfully detect exudates, it is useful to localize the optic disc in the retinal image under study because it appears in similar bright pattern, color and contrast as exudates appear. In this paper, we review different methods of optic disc localization and compare their results by performing experiments on standard and local database of fundus images.

Keywords
Diabetic retinopathy, optic disc, exudates, fundus image, color space, segmentation.

1. INTRODUCTION
Progressive diabetes (type 2 diabetes) may lead to Diabetic Retinopathy (DR), one of the leading causes of preventable blindness in the world. The disease progresses without symptoms of reduced vision, thus making treatment difficult. [1]. Systematic screening programs for diabetic eye diseases enables timely treatment that can reduce the risk of vision loss in the patients [2,3]. Non Proliferative Diabetic Retinopathy (NPDR) is characterized by swelling of blood vessels and they even leak blood and fluid. Proliferative Diabetic Retinopathy (PDR) is characterized by growth of abnormal new blood vessels on the surface of the retina and they also extend into vitreous [4-7]. The early pathologies that are associated with NPDR are microaneurysms (MA), hard exudates (HE), and cotton wool spots (CWS). Detection of the pathologies associated with DR is done from fundus images which are taken from a specialized camera called fundus camera.

The optic disk is the visible part of the optic nerve head within the retina. The optic disk is generally brighter than the surrounding area with an elliptical contour. The automatic determination of the optic disc in retinal fundus images aids the detection of exudates and cotton wool spots associated with DR. A number of studies have reported on automated localization of optic discs from fundus images [8-14]. In this paper, we compare performance of three methods of optic disc localization including the method proposed by us [15], by performing the experiments on a common set of digital fundus images. The rest of the paper is organized in following sections. Section 2 presents a review of pre-processing techniques available in the literature. In section 3, methods of detecting and extracting OD are discussed and conclusions are given in section 4.

2. PRE-PROCESSING TECHNIQUES
Pre processing is an important and essential step in Digital Image Processing. It aims at enhancing the visual appearance of images and to improve the manipulation of digital images. Choice of correct pre processing technique is very important because it emphasizes image artifacts. Preprocessing technique proposed in [11-13] consists of three steps:

i. conversion from RGB to HSI;
ii. applying median filter on I band to reduce noise;
iii. applying contrast limited adaptive histogram equalization (CLAHE) technique for contrast enhancement.

Figure 1 shows the results of pre-processing for a sample image [11, 12].

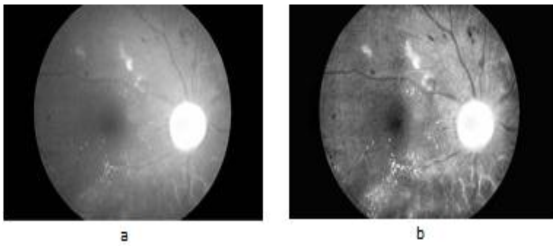

Fig 1: (a) Original I Band Image (b) Pre processed I Band image.

In [14, 15], pre-processing is done in three steps, namely
i. conversion of the image from RGB to CIELAB color space;
ii. applying median filter on L band to reduce noise; applying contrast limited adaptive histogram equalization (CLAHE) technique for contrast enhancement is applied.

Figures 2 and 3 shows the results obtained by pre- processing method described in [14] and [15] respectively.

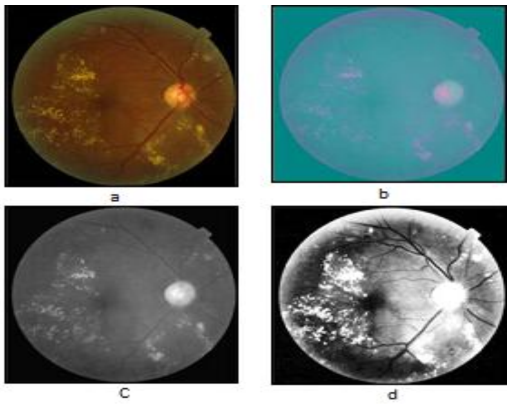

Fig 2: (a) Original RGB image (b) CIELAB color space image (c) L band Image (d) Pre-processed L band image.

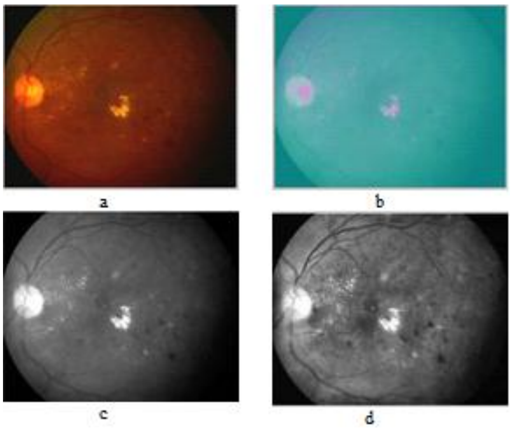

Fig 3: (a) Original RGB image (b) CIELAB color space image (c) L band Image (d) Pre-processed L band image.

3. OPTIC DISC SEGMENTATION

Segmentation of optic disc (OD) is a very important step in exudates detection. OD and hard exudates share common features such as color and contrast and have well defined edges [17-19]. This usually leads to increase in false positives. Hence, segmenting out OD before exudates detection is pre requisite. Akara Sopharak et al [13] proposed a method that uses entropy feature of the fundus image (I_{CLAHE}). The entropy is a statistical measure of randomness that can be used to characterize the texture of the input image. Entropy is given by the equation

Entropy=$[H(x)] = -\sum_{i\in w(x)} pi.\log_2(pi)$ (1)

where x is a set of all pixels in a sub window w(x), pi is the histogram count in sub window. Figure 4 shows the results of OD segmentation described in [13] for a sample image.

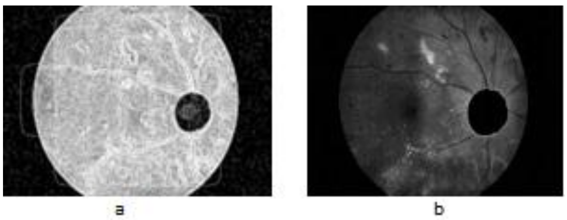

Fig 4: (a) Entropy image (b) OD area eliminated from the contrast enhanced image.

The steps involved in OD segmentation method presented by Akara Sopharak [13] and Feroui Amel et. al. [14] is described below.

i. The luminance channel (of L*a*b*) of the fundus image is used to enhance the contrast in [14] and in [13], intensity channel (of HSI) is used to enhance the contrast of the image.
ii. Blood vessel network from OD are eliminated using morphological closing operation [16]. For this, a circular structuring element of large size than the width of the vessels is used.
iii. A mask is created by applying thresholding operation, followed by morphological reconstruction by dilation.
iv. Finally, subtraction operation is performed on original I or L channel image and reconstructed image

Figure 5 and figure 6 shows the results of OD segmentation described in [13] and [14] respectively.

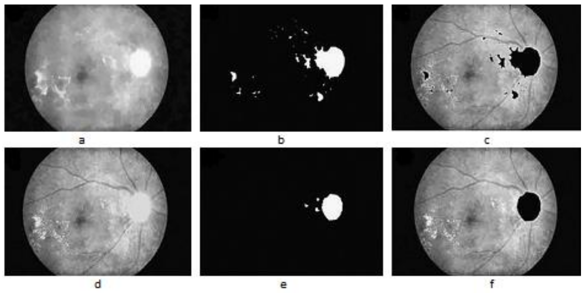

Fig 5: (a) Intensity image after closing operation, (b) thresholded image, (c) marker image, (d) reconstructed image, (e) thresholded result of difference image and (f) optic disc area eliminated from the contrast enhanced image.

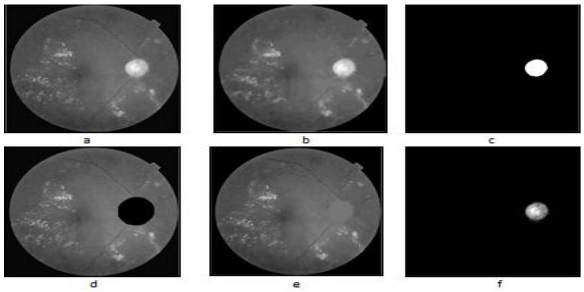

Fig 6: (a) L channel of original image (b) Elimination of the vascular tree (c) The result of thresholding (d) Marker image (e) reconstructed image (f) result of the optic disc segmentation by dilation.

In [15], as a prerequisite to exudates detection, we have proposed OD segmentation method taking into account brightness, shape and size features of OD.The steps involved are described below.

i. The blood vessel network is eliminated.
ii. Portion of image that contain OD is extracted using correlation coefficient.
iii. Circle fitting is applied using Hough Transform for circle, with radius range from 45pixels to 55pixels [22].
iv. Finally, the pixel intensities inside the circle are set to background intensity.

Figure 7 shows the result of OD segmentation method described in [15].

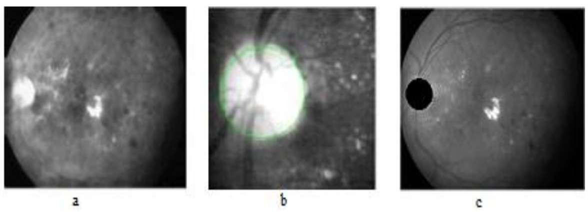

Fig 7: (a) Blood vessel eliminated (b) OD marked (c) OD pixels set to background.

4. RESULTS AND DISCUSSIONS

The HSI color space (hue, saturation and intensity) attempts to produce a more intuitive representation of color. Hue component represents what humans implicitly understand as color. The intention of CIELAB (or L*a*b* or Lab) is to produce a color space that is more perceptually linear than other color spaces. The main difference being HSI is device dependent and CIELAB is device independency [16].

CIELAB is more color complete space [21]. The methods discussed in this paper consider only one component of each color space i.e., L from CIELAB and I from HSI and both represents the same feature brightness. From the results obtained, we conclude that both color spaces contribute for pre-processing equally. The three OD segmentation methods discussed in this paper yielded good results. But these methods fail in situations where OD is partially visible or absent or not as bright as exudates as shown in figure 8(a) and also for in images where exudates cover larger area then OD as in figure 8(c). In such cases, the brightest and largest exudates group will be misclassified as OD as shown in figure 8(b) and figure 8(d) respectively. Red box represents the OD area misclassified as exudates and yellow box represents exudates area eliminated as OD. The failure of the methods in these cases may be attributed to the fact that methods consider the color intensity feature alone and do not ensure that the eliminated area is an OD as shown in figure 9.

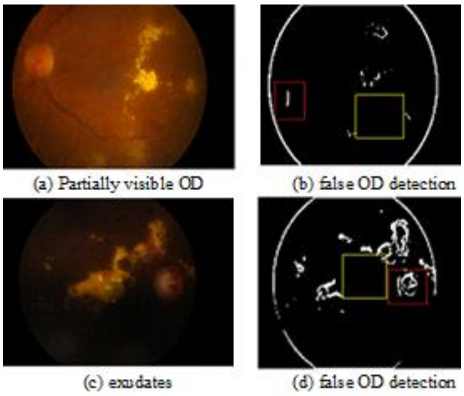

Fig 8: Example images of false OD detection

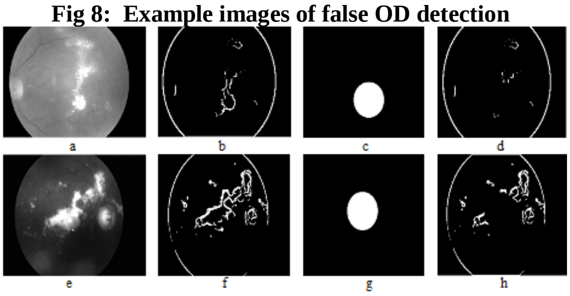

Fig 9: (a, e) intensity images (b, f) result of segmentation (c, g) mask (d, h) OD Eliminated images.

The problem of false OD detection is over come by the method proposed by us in [15]. Figure 10 shows the result obtained by performing experiments on such images. In figure 10(b) the group of bright exudates, almost circular, is rejected from being a candidate OD because radius of the area covered by the exudates group is smaller than the radius of OD [22]. Similarly, in figure 10(f) presents another example. Hence, we conclude that for successful OD elimination three features of OD namely, brightness, shape and size need to be considered.

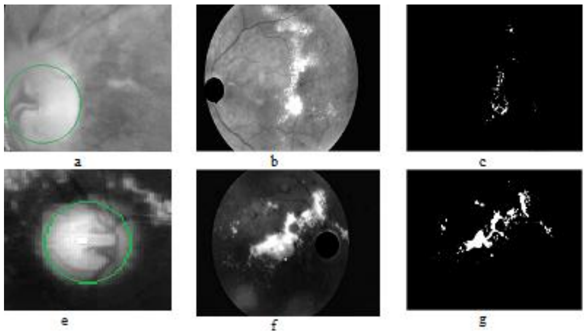

Fig 11: (a, e) OD marked image (b, f) OD pixels set to background (c, g) OD eliminated images.

5. CONCLUSIONS

Detection of OD is an essential pre-processing step for detection of exudates in DR images. Three prominent methods including the method proposed by us are compared. The performances of the said methods are compared by performing experiments on the fundus images obtained from Karnataka Institute of Diabetology, Bangalore [23]. The methods proposed in [12, 13, 14] fail to segment OD from the fundus images in case of images where OD is partially visible and in case where group of exudates dominates OD region. However, the method proposed in [15] reduces false OD detection and is better compared to [12, 13&14].

6. ACKNOWLEDGEMENT

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