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Detection of hard exudates using mean shift and normalized cut method

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ABSTRACT

As diabetic retinopathy (DR) is one of the main causes of loss of vision among diabetic patients, an early detection using automated detection techniques can prevent blindness among diabetic patients. Hard exudates constitute one of the early symptoms of DR and this paper describes a method for its detection using fundus images of retina, employing a combination of morphological operations, mean shift (MS), normalized cut (NC) and Canny's operation. This combined technique avoids over segmentation and at the same time reduces the time complexity while clearly delineating the exudates. Output of the proposed method is evaluated using public databases and produces sensitivity, specificity and accuracy as 98.80%, 98.25% and 98.65%, respectively. The ROC curve gives 0.984 as area under curve. The sensitivity, specificity, accuracy and area under curve of ROC indicate the effectiveness of the method.

1. Introduction

Diabetic retinopathy (DR) detection from fundus images of the retina [1] still remains a challenging task owing to the complexities involved in extracting and identifying the manifestations of the disease. The presence of blood vessels [2] can sometimes further complicate the detection process. DR can be classified as non-proliferative (NPDR) and proliferative (PDR). This NPDR progresses in several stages, with accompanying clinical symptoms. One of the earliest symptoms is the presence of hard exudates [3–8], caused when blood vessels get damaged and protein and lipid based particles gets leaked out of the damaged blood vessels and blood flow to the retina decreases. Fuzzy C-means (FCM) segmentation [4] has been used to cluster objects in the retina which possess similar brightness-hard exudates being an example. Since the optic disk (OD) has the same brightness [5] and contrast as hard exudates [5–7], removal of OD from fundus images of retina [6] should precede the segmentation process [7].

Normalized cuts proposed by Shi and Malik [9] along with color perception findings [10] have been widely used for image segmentation. The mean shift algorithm of Comaniciu and Meer [11] has also been used for image segmentation [12]. Classical mean shift (MS) causes over segmentation of the input images, while normalized graph cut (NGC) on input pixels introduces high time complexity. Thus, a combination of mean shift algorithm and normalized graph cut algorithm can address both these concerns and yield better segmentation

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results [13]. The objective of the present paper is to use a combination of these two algorithms to extract hard exudates (HEX) from retina fundus images.

In standard graph partitioning methods [9] a pixel or a group of pixels associated with nodes and edge weights defines the similarity or dissimilarity between the neighborhood pixels. In our earlier method [6] we have used a normalized cut segmentation method to extract exudates. In this paper we use the output of the pixel based mean shift algorithm to segment the pixels of same color/brightness followed by the N-cut algorithm to form meaningful clusters and thereby extract the HEX. In order to demarcate the hard exudates clearly we also used Canny's operator [14].

Earlier approaches have been outlined in Section 2, followed by the underlying theory of our proposed method in Section 3. Results are presented in Section 4 and conclusions and future work is given in Section 5.

2. Earlier work

Earlier work uses image processing based approaches [3–8,15–18]. Walter et al. [15] uses morphological reconstruction preceded by morphological filtering and watershed transformation for exudate detection and optic disk (OD) removal, respectively. Sagar et al. [16] localizes the OD by principal component analysis (PCA) followed by active contour for boundary detection of OD to exclude OD and obtain hard exudates. Li et al. [17] also removes OD by PCA and active shape model (ASM) and obtain exudates through region growing and edge extraction. Welfer et al. [18] use a coarse to fine strategy whereby the intensities of the pixels are rescaled between 0 and 1 and only intensity values >0.95 (region in which exudates lie) are further processed using morphological operators and a sensitivity of 70.48 and specificity of 98.84 is claimed. Several authors have additionally used soft computing for classification. These include artificial neural network by [19], and supervised machine learning by [20].

In graph partitioning methods, the image is considered as a weighted undirected graph. The pixel of input image defines the nodes of the graph whereas edge weights define the similarity or dissimilarity between the neighborhood pixels. The graph is then partitioned according to a determined criterion. Each partition of nodes as well as pixels is considered as segments of the image. More recently, multiscale enhancement filters have been used with graph-cut [21] and coarse to fine segmentation of retina images have also been reported [22].

3. Methodology

The methodology (Fig. 1) consists of morphological operation to remove the optic disk, application of mean shift algorithm for segmentation and finally the use of normalized cut technique to classify the hard exudates. The process as well as the necessary theory is described in following sub sections.

3.1. *Optic disk elimination*

Since the segmentation using the MS algorithm is based on the color of the region of interest (ROI) and the optic disk is of similar as the hard exudates an essential preprocessing step is the removal of OD. A procedure similar to [23] is followed for optic disk boundary detection and subsequent removal.

The method [23] is essentially based on active contour model using only region based statistics and obviating the use of edge stopping functions based on gradient information. This is a two step method where in first step bottom-hat transformation is performed on the red channel I_0 using linear elements are different locations, whereas bottom-hat transformation (denoted by φ_s^θ) is a residue between a closing and I_0 defined as, $\rho_s^\theta(I_0) = \varphi_s^\theta(I_0) - I_0$, where φ_s^θ is morphological closing with linear element s with orientation θ [23]. Now a max image is defined as $I_{\max}$, where $I_{\max} = \max_\theta \rho_s^\theta$ [23]. Now a smoothed image is obtained as $I_p = I_0 + I_{\max}$ [23]. In second step region based active contour method is used. Let I_0 be a given image such that $I_0 : \Omega \rightarrow \mathbb{R}$ where Ω be a bounded open subset of $\mathbb{R}^2$ with $\partial\Omega$ the boundary. Let $C(s) : [0,1] \rightarrow \mathbb{R}^2$ be a piecewise parameterized C curve [23]. The active contour model by Chan et al. (2001) [24], is as below,

$$F(c^+, c^-, C) = \mu \cdot Length\ (C) + \lambda^+ \int_{inside(C)} |I_0(x,y) - c^+|^2 dxdy + \lambda^- \int_{outside(C)} |I_0(x,y) - c^-|^2 dxdy \quad (1)$$

where c^+ and c^- are unknown constants representing the average value of I_0 inside and outside the curve respectively. We have two parameters $\mu \geq 0$ and $\lambda^+, \lambda^- \geq 0$ are weights for the regularizing and fitting terms respectively [24,23]. To minimize the fitting error in the above equation, the model [24] looks for the best partition of I_0 using only two values of c^+ and c^-, and with one edge C, the boundary between the two regions are represented by $\{I_0 \approx c^+\}$ and $\{I_0 \approx c^-\}$ [23]. The target object will be given by one of the regions and the curve will be the boundary of the object. In this case the OD will be detected and

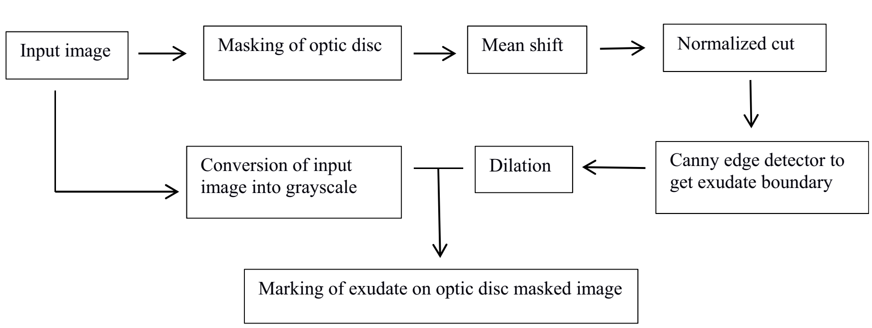

Fig. 1 – Flow chart of the proposed method.