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Improving microaneurysm detection in color fundus images by using context-aware approaches

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ABSTRACT

In this paper, we present two approaches to improve microaneurysm detector ensembles. First, we provide an approach to select a set of preprocessing methods for a microaneurysm candidate extractor to enhance its detection performance in color fundus images. The performance of the candidate extractor with each preprocessing method is measured in six microaneurysm categories. The best performing preprocessing method for each category is selected and organized into an ensemble-based method. We tested our approach on the publicly available DiaretDB1 database, where the proposed approach led to an improvement regarding the individual approaches. Second, an adaptive weighting approach for microaneurysm detector ensembles is presented.The basis of the adaptive weighting approach is the spatial location and contrast of the detected microaneurysm. During training, the performance of ensemble members is measured with respect to these contextual information, which serves as a basis for the optimal weights assigned to the detectors. We have tested this approach on two publicly available datasets, where it showed its competitiveness compared without previously published ensemble-based approach for microaneurysm detection. Moreover, the proposed approach outperformed all the investigated individual detectors.

1. Introduction

Diabetic retinopathy (DR) is a serious eye disease that originates from diabetes mellitus and is the most common cause of blindness in the developed countries. Early treatment can prevent patients to become affected from this condition or at least the progression of DR can be slowed down. One of the earliest signs of DR are microaneurysms (MAs). Thus, it is essential to recognize this lesion in the fundus of the eye in time. Computer-aided MA detection is based on the detailed analysis of digital fundus images (see Fig. 1 for an example). MAs appear as small circular dark spots on the surface of the retina.

The detection of MAs highly depends on the characteristics of the imaging device and other image properties (e.g. type of compression). As a result, some MAs can be easily spotted on the background of the retina, while the recognition of others are more difficult. Besides image characteristics, the spatial location also has influence on the detection of MAs (e.g. proximity of vessel parts, etc.)

In [2], Niemeijer et al. distinguishes three categories based on visibility: subtle, regular and obvious. An example for this categorization can be seen in Figs. 2 and 3. In the same study, they also investigate the detection of MAs near vessel. We extend these categorization with two additional categories with also taking into account the MAs which are detected on the macula and which are on the periphery of the image. Figs. 4 and 5 show examples for the spatial categories. We also provide a computational approach to determine the characteristics of the MAs. In this paper, we propose two approaches exploiting this categorization to improve microaneurysm detection ensembles.

First, to recognize MAs in the different categories, we measure the effect of using different preprocessing methods. As we can see later on, a preprocessing method can enhance the detection rate in a few categories, but there is no single best performing preprocessing method for all. To overcome this difficulty, we propose a context-aware selection approach of preprocessing methods for MA candidate extraction.

Moreover, we also present an adaptive weighting approach for ⟨preprocessing method, candidate extractor⟩ (⟨PP, CE⟩ for short) ensembles [3]. In [4], we introduced ⟨PP, CE⟩ ensembles for MA detection, which are effective tools for increasing the sensitivity of microaneurysm detectors by fusing the detections of the candidate extractors applied after different preprocessing methods. In [5], we introduced a selection technique for ⟨PP, CE⟩ ensembles, which resulted in the first ranked microaneurysm detector in the Reintopathy Online Challenge [2]. In this paper, we present an adaptive weighting approach for ⟨preprocessing method, candidate extractor⟩ ensembles. This approach assigns an optimal weight

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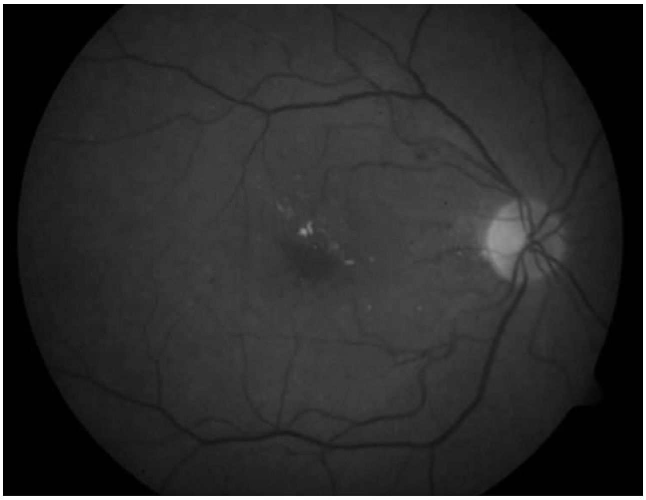

Fig. 1. An example fundus image from the DiaretDB0 [1] dataset.

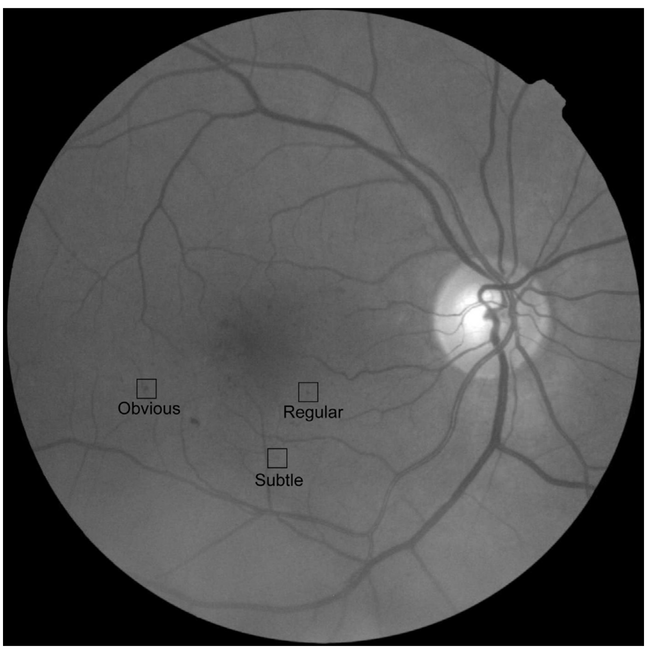

Fig. 2. Examples for MAs in different visual categories in a fundus image from the ROC [2] dataset.

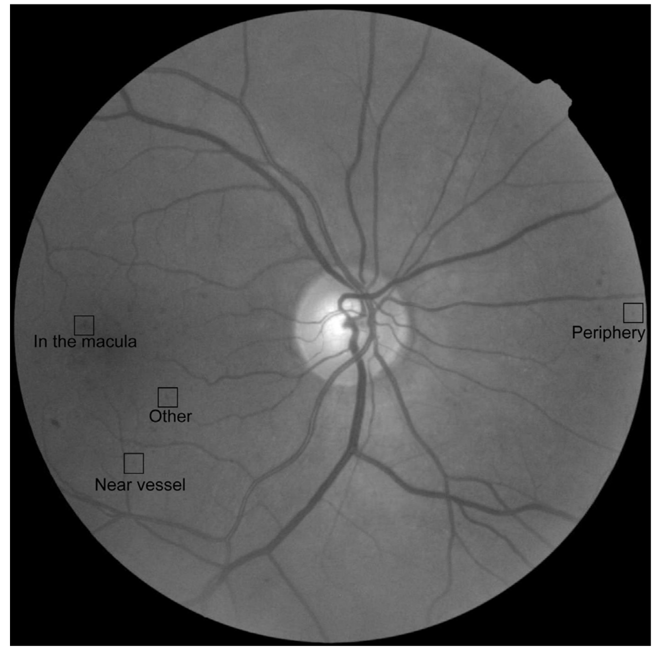

Fig. 4. Examples for MAs in different spatial categories in a fundus image from the ROC [2] dataset.

to each member of the ensemble based on their performance of detecting MAs having different contrast and spatial locations. The experimental results show that this method is competitive with our former ensemble-selection approach [5].

The rest of the paper is organized as follows: in Section 2 we review the state-of-the-art for microaneurysm detectors. Section 3 introduces the context-dependent preprocessing method selection approach for MA candidate extractors. The concept of ⟨PP, CE⟩ ensembles is described in Section 4, as well as the proposed adaptive weighting approach. Section 5 is devoted to the methodology we used in this paper. In Section 6, we discuss our experimental results, while we draw conclusions in Section 7.

2. State-of-the-art

MA detection is based on the detailed analysis of digital fundus images. State-of-the-art detection approaches usually start with the preprocessing of images, which is followed by candidate extraction. Finally, the extracted candidates are classified as MAs or non-MAs. The reason to separate the latter two steps is that the pixel-wise classification of the whole image would be very resource-demanding.

The vast majority of microaneurysm detectors can be organized into two categories: the ones based on mathematical morphology, and the others based on shape analysis with non-morphological tools. The largest family of morphology-based candidate extractors are originated from Lay [6] and Baudion [7]. These methods extract the vascular system by taking the maximum of multiple top-hat transformations with rotated linear structuring elements and subtract the resulting image from the original one. The candidates are then extracted by thresholding after applying a Gaussian filter. Oien et al. [8] was the first to apply similar techniques to color images. Spencer et al. [9] proposed a preceding shade correction step to this algorithm, while Frame et al. [10], Mendonca et al. [11], Hipwell et al. [12], Yang et al. [13], Cree et al. [14], Streeter et al. [15] and Fleming et al. [16] proposed modified variants. Mendonca

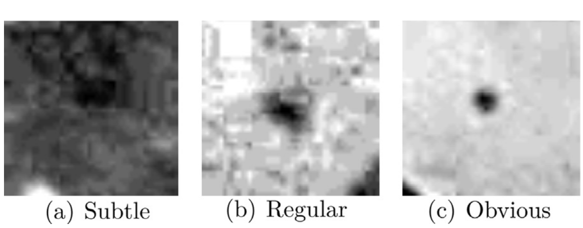

Fig. 3. Microaneurysm categories based on visibility.

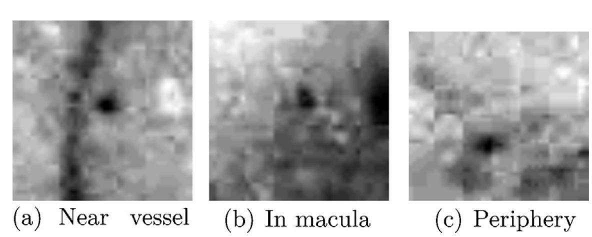

Fig. 5. Microaneurysm categories based on spatial location.