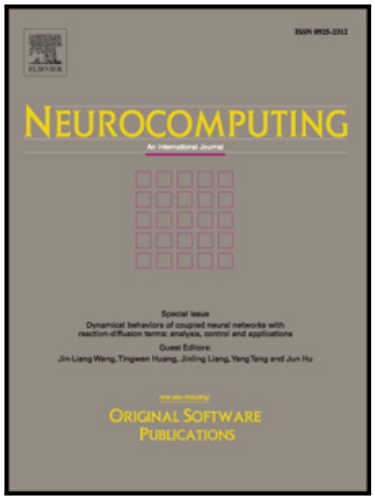
Communicated by Pingkun Yan

Accepted Manuscript



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PII: S0925-2312(17)31454-6
DOI: 10.1016/j.neucom.2017.08.033
Reference: NEUCOM 18825

To appear in: *Neurocomputing*

Received date: 3 November 2016
Revised date: 23 August 2017
Accepted date: 26 August 2017

Please cite this article as: Annan Li, Zhiheng Niu, Jun Cheng, Fengshou Yin, Damon Wing Kee Wong, Shuicheng Yan, Jiang Liu, Learning Supervised Descent Directions for Optic Disc Segmentation, *Neurocomputing* (2017), doi: 10.1016/j.neucom.2017.08.033

Learning Supervised Descent Directions for Optic Disc Segmentation

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Abstract

Optic disc (OD) segmentation is an important step in analyzing the color fundus image. Most existing approaches are based on the shape prior and visual appearance of the OD boundary. However, the current ways of integrating the shape and appearance are simple. We argue that the performance of OD segmentation can be improved by better shape-appearance modeling. In this paper, we propose to learn a sequence of supervised descent directions between the coordinates of OD boundary and their surrounding visual appearances for OD segmentation. In addition, we introduce the histograms of gradient orientations to represent the OD appearance. Experimental results on 6 datasets clearly show that the proposed method improve the OD segmentation and outperforms the state-of-the-art.

Keywords: Optic disc segmentation, supervised descent method.

1. Introduction

The optic disc (OD) or optic nerve head (ONH) is the point of exit for ganglion cell axons leaving the eye. Detecting OD boundary is a necessary step in analyzing color fundus image and has a wide range of applications. For example, the location of OD can be used to help estimating the locations of fovea [1]. The OD boundary is essential for calculating the cup-to-disc ratio, which is an important indicator in detecting glaucoma [2].

Many approaches have been proposed for OD boundary detection or segmentation in the literature. Presented methods can mainly be grouped into two categories according to the knowledge they rely on: the shape based and the appearance based. As the shape of an OD is approximately a circle or an ellipse, circular [3, 4, 5, 6] and elliptical [7, 8] templates are introduced to OD segmentation. However, since the actual OD shape is not necessarily a regular circle or ellipse, such templates are unable to capture localized shape variations of OD. As reported in [6], the average overlaps between the true OD shapes and the best fitting circles and ellipses are 92% and 97% respectively on the MESSIDOR dataset [9]. Instead of a single template, statistical shape models such as the active shape models (ASMs) [10] represent a OD shape as linear combinations of multiple manually marked OD shapes. It provides a more precise way of representing the OD shape. Typical applications of ASMs to the OD segmentation can be found in [11, 12, 13].

Besides the shape prior, characteristics of visual appearance are also widely used in OD segmentation. Because a relatively clear boundary can often be observed, contour based methods such as Canny edge detector [3, 5], level-set [14, 15], sliding band filter [16] and active contour [17, 18, 19, 20, 21, 22, 23, 24, 25] have been applied to OD segmentation. Based on the observation that OD is brighter than other area of retina, pixel classification based approaches are also proposed. Morales et al. [26] use the stochastic watershed transformation to get the binary mask of OD. Abramoff et al. [27] represent pixels in a color fundus image by physiologically plausible features such as Gaussian steerable filter bank, and separate the OD pixels from non-OD pixels by a k-nearest neighbor (kNN) classifier. Cheng et al. [28] use support vector machines (SVMs) to classify OD and non-OD pixels on a super-pixel level.

It should be pointed out that shape and appearance alone are both limited. They can be combined together for obtaining a better performance in practice. However, the existing ways of combining shape and visual appearance for OD segmentation are rather simple. For example, circular and elliptical templates are used as a post-processing step for refining the outputs of OD boundary [15, 26, 28, 24]. We argue that the performance of OD segmentation can be improved by better shape-appearance modeling. A novel OD segmentation method that directly learns the linear mapping between the coordinates of OD boundary and the surrounding visual appearance is proposed in this paper.

Our contribution lies in the following three aspects: 1) we introduce histograms of oriented gradients (HOG) [29] to represent the visual appearance of OD; 2) We model the connections between OD shape and appearance by learning a sequence of supervised descent directions [30], based on which a new OD segmentation method is developed; 3) Extensive experiments from 6 large-scale datasets show that the proposed method is effective and considerably outperforms existing approaches.

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