Chapter 16
An Improved Retinal Blood Vessel Detection System Using an Extreme Learning Machine

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ABSTRACT

Retinal images are commonly used to diagnose various diseases, such as diabetic retinopathy, glaucoma, and hypertension. An important step in the analysis of such images is the detection of blood vessels, which is usually done manually and is time consuming. The main proposal in this work is a fast method for retinal blood vessel detection using Extreme Learning Machine (ELM). ELM requires only one iteration to complete its training and it is a robust and fast network in all aspects. The proposal is a compact and efficient representation of retinal images in which the authors achieved a reduction up to 39% of the initial data volume, while still keeping representativeness. To achieve such a reduction whilst maintaining the representativeness, three features (local tophat, local average, and local variance) were used. According to the simulations carried out, this proposal achieved an accuracy of about 95% for most results, outperforming most of the state-of-art methods. Furthermore, this proposal has greater sensitivity, meaning that more vessel pixels are detected correctly.

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INTRODUCTION

Diseases, such as diabetic retinopathy, glaucoma, and hypertension can be diagnosed from retinal images. The detection of the blood vessels in these images plays an important role in the diagnosis. This detection task is usually done manually with specific tools and is very time consuming. In addition to using the detection of blood vessels in retinal images in the medical field, this technique can also be employed in personal identification systems. The main idea of this later use is for biometric devices where the retinal vascular network is used as input, as described in Köse et al. (2011). Therefore, the development of tools, methods, and techniques that automate vessel detection is very much in demand (Imani et al., 2015a).

Segmentation of blood vessels in retinal images have recently been carried out successfully with supervised and semi-supervised methods (Niemeijer et al., 2004b; You et al., 2011; Vega et al., 2015). Such methods follow the idea that each pixel is represented by a feature vector and then a supervised classifier classifies each pixel as vessel or non-vessel. Due to the size of retinal images, a large number of feature vectors are generated. Therefore, the choice of a classifier and the discriminant pixel descriptors becomes an important issue. Among the various existing neural networks, Extreme Learning Machine (ELM), is a neural network that belongs to the family of the single-hidden layer feedforward neural networks (SLFN). In SLFN the weights and the hidden layer biases can be randomly assigned, if the activation functions in the hidden layer are infinitely differentiable. Then the SLFNs can be simply considered as a linear system and the output weights of SLFNs can be analytically determined (Bala and Vijayachitra, 2015). Furthermore, ELM minimizes the empirical risk and only requires one iteration to complete its training.

In fact, using ELM for this particular task is not new in this field. Some methods using ELM employing different methodologies can be found in the literature (Sheeba and Vasanthi, 2011; Shanmugam and Wahida Banu, 2013; Bala and Vijayachitra, 2015). However, most of them lack a solid methodology. In one work for example, neither the setup parameters, nor the training methodology are clear (Sheeba and Vasanthi, 2011). Furthermore, some of them present results using only a few images from the dataset (Sheeba and Vasanthi, 2011; Shanmugam and Wahida Banu, 2013). Consequently, some questions concerning their methodology and achieved accuracies without any detailed explanations arise. Thus, it is difficult to make fair comparisons between models that employ a solid methodology and those that do not.

The objective of this work is to address the segmentation of blood vessels in retinal images using an ELM network. Considering that the performance of a classifier depends directly on the representativeness of the data used during the training stage, this work proposes a set of attributes extracted from the images. Such attributes represent information about the level of detail, mean and standard deviation of each pixel and its neighborhood. Thus, the main novelty of this work is the use of a compact and efficient representation of retina images, with a 36% reduction of the initial data in two of the three datasets used. Such compact and efficient representation decrease the computational cost because ELM requires the computation of inverse matrices and by reducing the matrix sizes, fewer computations are necessary to achieve the weight vectors and consequently less runtime. The proposed approach was evaluated using three common databases: the Digital Retinal Images for Vessel Extraction (DRIVE), the STructured Analysis of the Retina (STARE), and the High-Resolution Fundus (HRF). The first two have low-resolution images, while the last has high-resolution images.