A New Heuristic Function of Ant Colony System for Retinal Vessel Segmentation

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ABSTRACT

The automatic segmentation of blood vessels in retinal images is the crucial stage in any retina diagnosis systems. This article discussed the impact of two improvements to the previous baseline approach for automatic segmentation of retinal blood vessels based on the ant colony system. The first improvement is in features where the length of previous features vector used in segmentation is reduced to the half since four less significant features are replaced by a new more significant feature when applying the correlation-based feature selection heuristic. The second improvement is in ant colony system where a new probability-based heuristic function is applied instead of the previous Euclidean distance based heuristic function. Experimental results showed the improved approach gives better performance than baseline approach when it is tested on DRIVE database of retinal images. Also, the statistical analysis demonstrated that was no statistically significant difference between the baseline and improved approaches in the sensitivity (0.7388± 0.0511 vs. 0.7501±0.0385, respectively; P = 0.4335). On the other hand, statistically significant improvements were found between the baseline and improved approaches for specificity and accuracy (P = 0.0024 and 0.0053, respectively). It was noted that the improved approach showed an increase of 1.1% in the accuracy after applying the new probability-based heuristic function.

Keywords: *Automated Segmentation, Ant Colony System, Feature Selection, Heuristic Approach, Retinal Vessels*

1. INTRODUCTION

The automated segmentation of retinal vessels is the crucial stage in the diagnosis of many diseases such as hypertension (Leung et al., 2004), obesity (Mitchell et al., 2005), glaucoma (Wang et al., 2006) and diabetic retinopathy (Morello, 2007). These diseases often result in changes on bifurcations and tortuosity of retinal vascular. Hence, analyzing vessel features gives

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new insights to diagnose the corresponding disease early (Vijayakumari & Suriyanarayanan, 2012). Also for diagnosing the disease progress of certain patient along time, the blood vessels segmentation is necessary in automated registration of two retinal images of that patient at different times (Khan et al., 2011). Since the manual segmentation requires training and skill extensive research efforts have been devoted to automating the segmentation (Fraz et al., 2012a). Nevertheless, reliable vessel segmentation faces several challenges (You et al., 2011): "1) Retinal vascular has variant widths, lengths, bifurcations and tortuosity; 2) the narrow vessels usually may be lost by segmentation since they disappear among various local surroundings; and 3) various structures appear in the retinal image disrupt segmentation such as optic disc, fovea and exudates".

This article proposes two improvements of the previous baseline approach (Asad et al., 2012a) used for automatic segmentation of blood vessels in retinal images based on the ant colony system (ACS) (Dorigo & Gambardella, 1997). The first improvement is in features where the length of previous features vector used in segmentation is reduced from eight to five since four less significant features are replaced by a new more significant feature when applying the correlation-based feature selection heuristic (CFS) (Hall, 2000). The second improvement is in ACS where a new probability-based heuristic function is applied instead of the previous Euclidean distance based heuristic function. Since the large number of computed features increases the classification complexity, time and reduces accuracy. So that, feature selection is an essential step for successful classification because it removes irrelevant features and achieves less complex, more accurate and faster classification. In this paper, CFS is used and it recommended the best feature vector consisting of five features out of fifteen features for segmentation. The new performance of this improved approach is evaluated on a publicly available database of retinal images for scientific research DRIVE (Staal et al., 2004) in terms of the sensitivity, specificity and accuracy.

The rest of this article is organized as follows: Section 2 surveys the previous popular related work. Section 3 gives scientific background of the used features, CFS and ACS. Section 4 presents the previous baseline approach and its two improvements. Section 5 reports the results of experimental evaluation of improved approach. The conclusions and future work are finally presented in Section 6.

2. RELATED WORK

The automatic segmentation methods of retinal blood vessels are categorized into two main categories: unsupervised and supervised. For the unsupervised category, they are classified into methods based on *matched filter*, *vessel tracking*, *mathematical morphology* and *bio-inspired algorithms*. For the methods based on *matched filter*, the matched filter is 2-D kernel convolved with the image to search for three features of retinal vessel in the image at unknown position and orientation. These features should be considered when designing a matched filter; 1) intensity profile of cross-section of a retinal vessel is approximated by Gaussian curve so the matched filter has Gaussian profile; 2) the retinal vessel has little curvature so it can be approximated by piecewise linear segments and 3) the retinal vessel diameter decrease as it moves outward from the optic disk. The kernel is rotated in multiple orientations to detect all vessels in all directions so it takes more computation overhead. The response of matched filter is high with retinal vessels which have the same standard deviation of Gaussian function modeled by matched filter so it may miss retinal vessels that have different profiles. The illumination variation in background and presence of pathologies increases false positive detections resulted by the matched filter. Chaudhuri et al. (1989) applied 2-D linear kernel rotated in twelve orientations to match retinal vessels in all directions. The maximum response of matched filter in all orientations