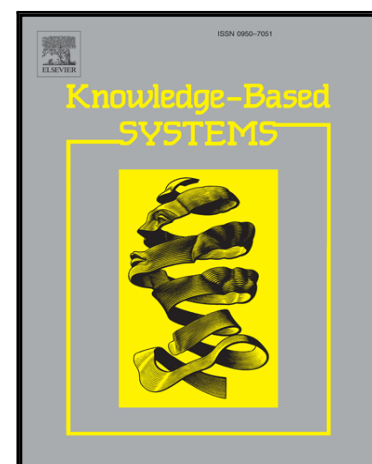


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Performance analysis of descriptive statistical features in retinal vessel segmentation via fuzzy logic, ANN, SVM, and classifier fusion

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Abstract:

Diabetic retinopathy is the most common diabetic eye disease and a leading cause of blindness in the world. Diagnosis of diabetic retinopathy at an early stage can be done through the segmentation of blood vessels of the retina. In this work, the performance of descriptive statistical features in retinal vessel segmentation is evaluated by using fuzzy logic, an artificial neural network classifier (ANN), a support vector machine (SVM), and classifier fusion. Newly constructed eight features are formed by statistical moments. Mean and median measurements of image pixels' intensity values in four directions, horizontal, vertical, up-diagonal, and down-diagonal, are calculated. Features, F1, F2, F3, and F4 are calculated as the mean values and F5, F6, F7, and F8 are calculated as the median values of a processed pixel in each direction. A fuzzy rule-based classifier, an ANN, a SVM, and a classifier fusion are designed. The publicly available DRIVE and STARE databases are used for evaluation. The fuzzy classifier achieved 93.82% of an overall accuracy, 72.28% of sensitivity, and 97.04% of specificity. For the ANN classifier, 94.2% of overall accuracy, 67.7% of sensitivity, and 98.1% of specificity are achieved on the DRIVE database. For the STARE database, the fuzzy classifier achieved 92.4% of overall accuracy, 75% of sensitivity, and 94.3% of specificity. The ANN classifier achieved the overall accuracy, sensitivity, and specificity as 94.2%, 56.9%, and 98.4%, respectively. Although the overall accuracy of the SVM is calculated lower than the fuzzy and the ANN classifiers, it achieved higher sensitivity rates. Designed classifier fusion achieved the best performance among all by using the proposed statistical features. Its overall accuracy, sensitivity, and specificity are calculated as 95.10%, 74.09%, 98.35% for the DRIVE and 95.53%, 70.14%, 98.46 for the STARE database, respectively. The experimental results validate that the descriptive statistical features can be employed in retinal vessel segmentation and can be used in rule-based and supervised classifiers.

Key words: Retinal vessel segmentation, statistical features, classification, fuzzy logic, ANN, SVM, classifier fusion.

1. Introduction:

Diabetic retinopathy (DR) is a major cause of visual impairment, and is the leading cause of blindness around the world. The number of people diagnosed with this disease is rapidly increasing. DR is classified as a vascular disorder since most of the clinically visible lesions of DR are vascular in nature. Retinopathy has two stages: An early, non-proliferative stage and an advanced, proliferative or neo-vascular stage (Tang & Kern, 2011). The early, non-proliferative stage of retinopathy is characterized by damaged small retinal blood vessels and rarely has clinical significance but the amount and severity of the changes in this stage provides clues about the progress toward the advance stage of the disease. It is reported that patients with early DR typically have retinal micro-aneurysms (Kern, 2007; Nunes et al., 2009), which are swelled damaged blood vessels. Micro-aneurysms appear as red dots on dilated fundus-scopic examination. These micro-aneurysms may leak fluid leading to swelling, bleeding, and eventually vision loss. The advanced, neo-vascular stage of retinopathy is characterized by retinal neo-vascular events and impairment of vision (Kavitha and Palani, 2014; Tang & Kern, 2011).

DR originates from the consequences of high sugar level in blood (hyperglycemia). People with diabetes mellitus have a high risk of vision loss since DR damages retinal vessels (Davidson et al., 2007). DR stimulates ischemia that causes a growth of new blood vessels that may subsequently bleed or cause retinal detachment, and breakdown of the blood-retinal barrier that may lead to fluid leakage, diabetic macular edema, and damage to photoreceptors (Ciulla, Amador, & Zinman, 2003).

Age-related macular degeneration is another main source of irreversible visual loss in the center of the visual field. It is usually seen in elder people (Bressler, Bressler, & Fine, 1988). The eye disease arises from damage to the macula, which is responsible for sharp, peripheral and color vision (Tezel, Bora, & Kaplan, 2004). Intraocular pressure is a major risk factor for optic nerve damage and causes vision loss that is called glaucoma. A study by

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