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Automated Detection System for Diabetic Retinopathy Using Two Field Fundus Photography

Sharath Kumar P N[a,*], Deepak R U[a], Anuja Sathar[b], Sahasranamam V[b], Rajesh Kumar R[a]

[a]*Centre for Development of Advanced Computing, Thiruvananthapuram-695033, India*
[b]*Regional Institute of Ophthalmology,Thiruvananthapuram-695035, India*

Abstract

Diabetic retinopathy (DR) is a leading cause of vision loss, caused by damage to the retina from complications of diabetes. Analysis of the retinal photographs for key characteristics of DR can result in early diagnosis and better management of DR. This paper presents a method for automated analysis and classification of the retina as DR or non-DR using two-field mydriatic fundus photography. The optic disc region is located by multi-level wavelet decomposition and recursive region growing from an automatically identified seed point. Blood vessels are extracted by applying histogram analysis on the two median filtered images. Red lesions are detected using three stage intensity transformation and white lesions from multi-level histogram analysis. The final classification of the retina as DR or non-DR is based on an aggregate of the lesions extracted from each image. The proposed method has been validated against diagnosis by a panel of expert ophthalmologists on images from 368 patients. The observed sensitivity and specificity were 80% and 50% respectively. The results show that automated screening based on two-field photography can be applied in routine screening

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Keywords: diabetic retinopathy; automatic detection; fundus images; red lesions; white lesions; microaneurysms; hemorrhages; exudates; cotton-wool spots

1. Introduction

Diabetic Retinopathy (DR) is the disease affecting blood vessels in the retina where capillary vessels in particular are vulnerable to high glucose levels caused by diabetes. DR is the most common complication of diabetes and the leading cause of blindness. The most significant predictor of the prevalence of DR is the duration of the diabetes[1].

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DR is divided into various stages. The earliest signs of DR are microaneurysms (MA), dot & blot hemorrhages (HE), cotton-wool spots and exudates that result from abnormal permeability and non-perfusion of capillaries. These early signs are known as non-proliferative DR (NPDR). Fluid leaking from retinal capillaries indicates a further progression of the disease. This may lead to sight threatening diabetic retinopathy, if the leakage is located in the area of most acute vision, the macula. Advanced stage of DR, proliferative DR (PDR), develops from occluded capillaries that lead to retinal ischemia and formation of new vessels on the surface of the retina either near optic disc (OD) or in the retinal periphery[2]. Other complications of PDR include detachment of the retina due to scar tissue formation and new blood vessels bleeding into vitreous chamber giving rise to vitreous hemorrhage[3].

In India, there are approximately 31.7 million diabetes patients and every year 1.7 million new patients get added to this[4]. Of these approximately 5.6 million patients are thought to suffer from DR. Symptoms of disease will only surface during the advanced stages of the disease either by the development of macular edema or PDR where treatment will be aimed at preventing further vision loss than restoring lost vision. Asymptomatic nature of the disease during the early stage mandates systematic and periodic screening of apparently healthy person for the risk of DR that can be prevented by medical intervention[2]. Studies by Kristinsson et al.[5] and Singer et al.[6] points that systematic screening and timely treatment significantly reduces vision loss and costs to the society.

Although there are numerous methods for the detection of DR like direct or indirect ophthalmology, Optical Coherence Tomography (OCT), retinal imaging using digital fundus camera has been widely used for screening and diagnosis of DR. Seven standard field stereoscopic color photography as defined by the ETDRS is the gold standard for detecting and classifying DR[7]. Even then practicing this standard for DR screening is quite impractical as it requires highly skilled photographer and longer time for each patient imaging and increased patient co-operation, in addition to the logistics of storing and handling large number of images. Grading for DR and assessing the need for referral treatment from remote diagnosis of has been reliably executed in telemedicine applications8. From the studies, it has been identified that a single field photography including macula may be sufficient[9]. In this study, we follow the two field fundus photography. One image with macula as centre covering majority of temporal retina and smaller part of nasal retina; while the second image field with optic disc as the center further increases the coverage of nasal retina. Thus by combining the two fields, sufficiently good coverage of retina is obtained.

In India, patient to ophthalmologist ratio is 100,000:1[10], with such an enormous disparity in ratios an ophthalmologist will have no time for blindness preventive surgeries but will be instead flooded with general eye-check-ups. Computer Aided Detection (CAD) can play a pivotal role in addressing prevention of avoidable blindness by automated detection of retinal pathologies and can thus alleviate the burden of screening from ophthalmologists. It also needs to be understood that 80% of diabetics will have will have no sign of DR[4]. Hence with automated screening, only those patients with likely pathology need to be referred, thereby reducing the workload of ophthalmologists. The method described in this paper is intended to be a first step towards automated DR screening system.

Similar work has been done by Keith Goatman et al.[11-14] where primary focus was microaneurysm detection. In this paper, we use alternate techniques for detection of red lesions like microaneurysm, dot, blot and flame hemorrhages. Additionally, detection of white lesions like exudates and cotton wool spots which have received lesser attention among researchers is also included in this work. The techniques described in this paper are following the previous work of Sharath Kumar et al.[18, 20] and applied on a larger number of retinal images and finally giving the decision of diagnosis screening compared to clinical evaluation.

This paper presents the implementation of the screening system as a four stage process. In the first step, the retinal images are normalized via bi-cubic interpolation, local contrast enhancement and background subtraction. The second step is to automatically locate optic disc and blood vessels regions. The third step is to recognize signs of DR, namely red and white lesions. Finally, the information from both fields are accumulated and the retina is classified as DR or non-DR.