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Automated screening system for retinal health using bi-dimensional empirical mode decomposition and integrated index

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ABSTRACT

Posterior Segment Eye Diseases (PSED) namely Diabetic Retinopathy (DR), glaucoma and Age-related Macular Degeneration (AMD) are the prime causes of vision loss globally. Vision loss can be prevented, if these diseases are detected at an early stage. Structural abnormalities such as changes in cup-to-disc ratio, Hard Exudates (HE), drusen, Microaneurysms (MA), Cotton Wool Spots (CWS), Haemorrhages (HA), Geographic Atrophy (GA) and Choroidal Neovascularization (CNV) in PSED can be identified by manual examination of fundus images by clinicians. However, manual screening is labour-intensive, tiresome and time consuming. Hence, there is a need to automate the eye screening. In this work Bi-dimensional Empirical Mode Decomposition (BEMD) technique is used to decompose fundus images into 2D Intrinsic Mode Functions (IMFs) to capture variations in the pixels due to morphological changes. Further, various entropy namely Renyi, Fuzzy, Shannon, Vajda, Kapur and Yager and energy features are extracted from IMFs. These extracted features are ranked using Chernoff Bound and Bhattacharyya Distance (CBBD), Kullback–Leibler Divergence (KLD), Fuzzy-minimum Redundancy Maximum Relevance (FmRMR), Wilcoxon, Receiver Operating Characteristics Curve (ROC) and *t*-test methods. Further, these ranked features are fed to Support Vector Machine (SVM) classifier to classify normal and abnormal (DR, AMD and glaucoma) classes. The performance of the proposed eye screening system is evaluated using 800 (Normal=400 and Abnormal=400) digital fundus images and 10-fold cross validation method. Our proposed system automatically identifies normal and abnormal classes with an average accuracy of 88.63%, sensitivity of 86.25% and specificity of 91% using 17 optimal features ranked using CBBD and SVM-Radial Basis Function (RBF) classifier. Moreover, a novel Retinal Risk Index (RRI) is developed using two significant features to distinguish two classes using single number. Such a system helps to reduce eye screening time in polyclinics or community-based mass screening. They will refer the patients to main hospitals only if the diagnosis belong to the abnormal class. Hence, the main hospitals will not be unnecessarily crowded and doctors can devote their time for other urgent cases.

1. Introduction

PSED such as glaucoma, AMD and DR are the leading causes of visual loss worldwide [1]. Recent report from World Health Organization (WHO) reveal that 285 million people are visually impaired globally, among them 39 million are blind and 246 million are having low vision [1]. Glaucoma is caused due to increase in Intra-Ocular Pressure (IOP) of the eye causing changes in retinal structures [2]. Hence, it may result in peripheral vision loss and subsequently causing blindness, if not treated early [3,4]. Approximately 12.3% of blindness cases reported worldwide are due to glaucoma [5]. AMD is caused due to degeneration of visual cells in the macula. It affects the people aged above 60 years and may lead to vision loss. Worldwide, 20–25 million people are affected due to AMD and among them 8 million people suffer with severe blindness [6,7]. Complications of Diabetes Mellitus (DM)

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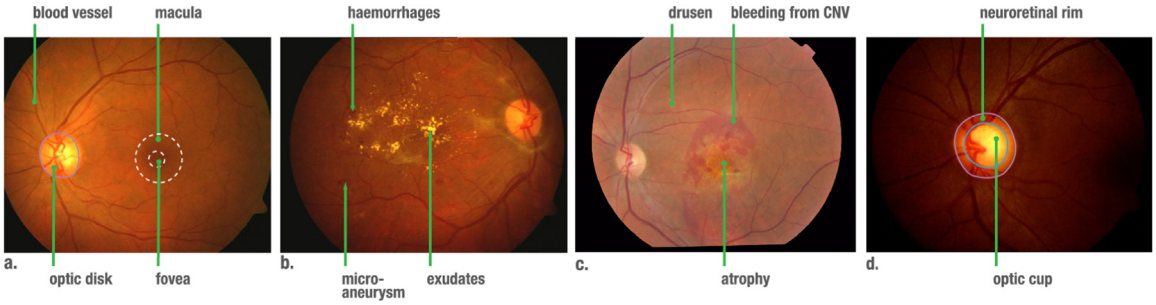

Fig. 1. Representative retinal images: (a) normal; (b) diabetic retinopathy; (d) age-related macular degeneration; (c) glaucoma.

Table 1
Details of AMD, DR and glaucoma eye diseases.

	Glaucoma	AMD	DR (grading)
Types (stages)	Primary Open Angle Glaucoma (POAG)	Dry AMD	Non-Proliferative Diabetic Retinopathy (NPDR)
	Primary Angle Closure Glaucoma (PACG)	Wet AMD	Proliferative Diabetic Retinopathy (PDR)
			Macular Edema (ME)
Signs and symptoms	Usually no symptoms	Blurring of central vision	Blurred vision
	In POAG and PACG usually presents with symptoms	Straight lines looks wavy	
	Screening is mostly done for POAG as it is symptomless	Scotoma or non-seeing areas in the centre of visual field	
Clinical features (optic nerve head and retinal changes)	Changes in Optic Nerve Head (ONH)	Drusen	MA
	Loss of neuroretinal rim	Retinal pigmentation	Hard Exudates
	Defects in Retinal Nerve Fibre Layer (RNFL)	GA	CWS
	Peripapillary Atrophy (PPA)	CNV	HA
			ME
Causes	Rise in IOP	Break down of light sensitive cells in the macula due to ageing	Diabetes and its complications
	Suspected blockage of the drainage canals. Obvious cause not known		
Diagnostic techniques	Visual field test	Visual acuity test	Visual acuity test
	ONH assessment using ophthalmoscopy	Amsler grid test	Retinal examination using direct slit lamp
	RNFL assessment using Scanning Laser Ophthalmoscope (SLO) and Polarimetry	Slit lamp	Fundus photography
	Heidelberg Retinal Tomography (HRT)	Retinal fundus photography	OCT
	Optical Coherence Tomography (OCT)	Fluorescence Angiography (FA)	Fundus Fluorescence Angiography (FFA)
		OCT	
		Autofluorescence imaging	
		Infrared imaging	
		Doppler imaging	
Treatment methods	Surgery	Non-thermal laser	Optimal control of diabetes
	IOP lowering drops	Photodynamic therapy	Laser photocoagulation
		Zinc and antioxidant vitamins	Grid laser treatment
			Pan-retinal photocoagulation
			Pars plana vitrectomy
Citations	[4,10–14]	[6,15,7,16]	[17–20]

leading to DR may result in vision loss and blindness [8]. The WHO has estimated that DR is responsible for 4.8% of the blindness globally [9]. The types (stages), symptoms, clinical features, causes, diagnostic techniques and treatment methods of DR (See Fig. 1b), AMD (See Fig. 1c) and glaucoma (See Fig. 1d) are briefly tabulated in Table 1.

AMD and DR are completely screened based on retinal features, whereas glaucoma screening involves IOP and visual field screening as well [19]. Early detection of ocular diseases may prevent the vision loss or blindness [18,21]. In general, fundus photography (see Fig. 1) is extensively used for screening of DR, glaucoma and AMD [19]. Hence, several Computer Aided Diagnosis (CAD) systems have been proposed for automated diagnosis of DR, glaucoma and AMD.

Recently, multiscale Amplitude Modulation (AM)-Frequency Modulation (FM)-based feature extraction is proposed in [22] for automated DR screening. Instantaneous Frequency (IF) and Instantaneous Amplitude (IA) are generated from the lesions to characterize DR. Their method yielded an Area Under receiver operator characteristics Curve (AUC) of 0.89. However, the presence of noise and blurring of retinal images are not considered. Mathematical morphology and thresholding is used in [23] to segment HE and CWS for DR grading and reported an accuracy of 97%. The threshold value is chosen by human observer by trial and error method, hence HE segmentation may vary for other set of images. Quellec et al. [24] proposed Gaussian derivatives and Gabor wavelet to design optimal filter for DR detection and showed an AUC of 0.927. Their method is able to detect both MA and drusen. Gray-Level Co-occurrence Matrix (GLCM) and run length based texture features and Diabetic Retinopathy Risk Index (DRRI) are used in [25] to grade DR and presented an accuracy of 85.20%.