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ARTICLE

AUTOMATED LOCALIZATION OF OPTIC DISC IN RETINAL VASCULAR CHANGES AND DIABETIC RETINOPATHY

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ABSTRACT

Glaucoma is one of the most common causes of blindness. The number of people having severe vision loss in developing countries. Robust mass screening may help to extend the symptom-free life for affected patients. To realize mass screening requires a cost-effective glaucoma detection method which integrates well with digital medical image processing. To address these requirements, the proposed novel low cost automated glaucoma diagnosis system based on hybrid feature extraction from digital fundus images. This paper discusses a system for the automated identification of normal and glaucoma classes using Higher Order Spectra (HOS), Trace Transform (TT), and Discrete Wavelet Transform (DWT) features. The same features with SVM classifier produce a less accuracy. So the proposed extracted features are fed to a Expectation Maximization (EM) classifier to achieve a good result. This was able to identify glaucoma and normal images. Furthermore, we propose a novel integrated index called Glaucoma Risk Index (GRI) which is composed from HOS, TT, and DWT features, to diagnose the unknown class using a single feature. Hence this GRI will aid clinicians to make a faster glaucoma diagnosis during the mass screening of normal/glaucoma images.

KEY WORDS
Discrete Wavelet Transform (DWT), Expectation Maximization(EM), Glaucoma Risk Index

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INTRODUCTION

The human eye is a complex biological device. The mechanism of cameras often compared with the working of the eye, as shown in [Fig.1]. Light entering the eye is first refracted when it passes through the cornea. It then passes through the pupil and is further refracted by the lens. Finally, it reaches the retina and is converted to electrical signals by photosensitive photoreceptor. The electrical signals are transmitted to the brain along the optic nerve. The cornea is the transparent front part of the eye. It is the first structure that is able to refract the light entering the eye. However, the focal distance of the cornea is fixed, which means that the cornea can only refract light with a constant angle. The lens, on the other hand, can adjust its focal distance so that incoming light can be focused on the retina. The lens is a transparent structure lying behind the iris and the pupil. The iris is a membrane organ in the eye. It controls the diameter and size of the pupil and hence the amount of light reaching the retina. The movement of iris is controlled by the iris dilator muscle. The pupil is an opening in the center of the iris. It allows light to enter the eye and reaches the lens. The pupil appears to be black because most of the light entering the pupil is absorbed. The vitreous is the transparent, colorless, gelatinous mass that fills the space between the lens and the retina. It is also referred to as the vitreous body or vitreous humor. Unlike the fluid in the frontal part of the eye which is continuously replenished, the gel in the vitreous is stagnant. So if blood or cytosol gets into the vitreous, they may not be reabsorbed for an extended period of time. A vitreous hemorrhage is a typical symptom of diabetic retinopathy. The optic disc or optic nerve head is the location where ganglion cell axons exit the eye. The optic nerve is a bundle of more than one million nerve fibers. The optic nerve connects the retina to the brain. It is also the place where all retinal blood vessels originate and converge. The optic disc is placed 3-4mm to the nasal side of the fovea [1,2,3].

Retinal Images

The retina is a layered tissue lining the interior of the eye that enables the conversion of incoming light into a neural signal that is suitable for further processing in the visual cortex of the brain. It is thus an extension of the brain. The ability to image the retina and develop techniques for analyzing the images is of great interest. As its function requires the retina to see the outside world, the involved ocular structures have to be optically transparent for image formation. Thus, with proper techniques, the retina is visible from the outside, making the retinal tissue, and thereby brain tissue, accessible for imaging noninvasively. Because the retina's function makes it a highly metabolically active tissue with a double blood supply, the retina allows direct noninvasive observation of the circulation shown in [Fig.2].Thus, because of its architecture dictated by its function both diseases of the eye, as well as diseases that affect the circulation and the brain can manifest themselves in the retina. These include ocular diseases, such as macular degeneration and glaucoma, the first and third most important causes of blindness in the developed world. A number of systemic diseases also affect the retina. Complications of such systemic diseases include diabetic retinopathy from diabetes, the second most common cause of blindness in the developed world, hypertensive retinopathy from cardiovascular disease, and multiple sclerosis. Thus, on the one hand, the retina is vulnerable to organ-specific and systemic diseases, while on the other hand, imaging the retina allows diseases of the eye proper, as well as complications of diabetes, hypertension and other cardiovascular diseases, to be detected, diagnosed and managed. This review focuses on quantitative approaches to retinal image analysis. Principles of 2-D and 3-D retinal imaging are outlined first. Special

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emphasis is given to fundus and optical coherence tomography (OCT) image analysis and its use to provide comprehensive descriptions of retinal morphology and function. The described methods cover the developments of the past decade and were selected with respect to their potential for screening-motivated computer-aided detection of retinal abnormalities as well as for translational clinical applications including improved retinal disease diagnoses and image-guided retinal therapy. As such, the methods presented are expected to influence routine clinical patient care in the years to come [4,5].

Disease Specific Analysis of Retinal Images

The everyday cost associated with eye care providers' decisions and the ever-increasing numbers of retinal images to be reviewed are the major motivations for the adoption of image analysis in ophthalmology. Clearly, since clinicians are costly experts, they need to optimize the time devoted to each patient, whether their cost is born by patients, third party insurers, or society as a whole. As presented in the following sections, the development of new imaging technology invariably results in rapidly increasing amounts of data collected as part of any specific retinal imaging exam. The amount of information provided by the current generation of scanners and cameras is already exceeding the limit of clinicians' ability to fully utilize it. When factoring in that clinicians are subjective, and their decisions suffer from the inter- and intra-observer variability, the need for reliable computerized approaches to retinal image analysis is more than obvious, if for no other reason, than to increase the precision with which patients are managed. An additional important reason for incorporating automated analyses of retinal images in patient management is the potential societal benefit of increasing clinician productivity in a routine population screening setting. While the patient management decision making and population screening scenarios are somewhat different and specific, they both require quantitative retinal image analysis to be rapidly translated to everyday use [6,7].

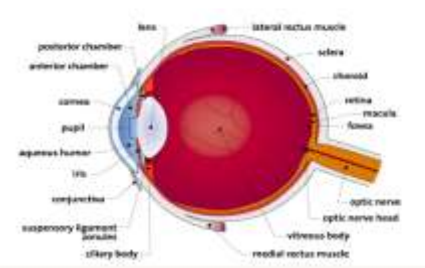

Fig. 1: Human Eye Structure

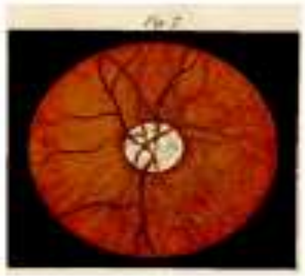

Fig. 2: Image of human retina

Retinal Camera & Photograph

A camera attached to an indirect ophthalmoscope aimed at photographing the image of the fundus of the eye. This image is produced by the objective of the ophthalmoscope at the first focal point of the objective of the viewing microscope (and of the camera), which forms an image on the film. A flip mirror within the optical path of the viewing microscope allows the observer to view the image of the fundus and focus it, thus ensuring that the image being photographed is as clear as that being viewed. Fundus cameras usually require a dilated pupil of about 4 mm and their fields of view extend up to 45°. They provide an objective photographic record of any condition in the fundus. They can also be used to take photographs of the anterior segment of the eye.

Currently, regular screenings are conducted and retinal images are obtained using fundus camera. However, a large amount of images are obtained from these screenings and it requires trained ophthalmologists to spend a lot of time for manual analysis and diagnosis. Hence, automatic detection is desired as it can help to improve productivity and be more cost effective shown in [Fig.3 &4].

Fig. 3: Retinal camera

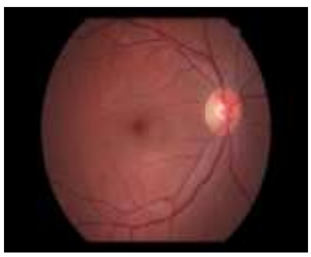

Fig. 4: Normal eye retinal photograph

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Glaucoma

Glaucoma is a condition that causes damage to eye's optic nerve and gets worse over time. It's often associated with a buildup of pressure inside the eye. Glaucoma tends to be inherited and may not show up until later in life. The increased pressure, called intraocular pressure, can damage the optic nerve, which transmits images to the brain. If damage to the optic nerve from high eye pressure continues, glaucoma will cause permanent loss of vision. Without treatment, glaucoma can cause total permanent blindness within a few years. Glaucoma usually occurs when pressure increases in eye shown in [Fig.5&6]. This can happen when eye fluid isn't circulating normally in the front part of the eye. Normally, this fluid, called aqueous humor, flows out of the eye through a mesh-like channel. If this channel becomes blocked, fluid builds up, causing glaucoma. The direct cause of this blockage is unknown, but doctors do know that it can be inherited, meaning it is passed from parents to children .Less common causes of glaucoma include a blunt or chemical injury to the eye, severe eye infection, blockage of blood vessels in the eye, inflammatory conditions of the eye, and occasionally eye surgery to correct another condition. Glaucoma occurs in both eyes, but it may involve each eye to a different extent. Open-angle glaucoma. Also called wide-angle glaucoma, this is the most common type of glaucoma. The structures of the eye appear normal, but fluid in the eye does not flow properly through the drain of the eye, called the trabecular meshwork. Angle-closure glaucoma. Also called acute or chronic angle-closure or narrow-angle glaucoma, this type of glaucoma is less common but can cause a sudden buildup of pressure in the eye. Drainage may be poor because the angle between the iris and the cornea is too narrow.To diagnose glaucoma, an eye doctor will test your vision and examine your eyes through dilated pupils. The eye exam typically focuses on the optic nerve which has a particular appearance in glaucoma. In fact, photographs of the optic nerve can also be helpful to follow over time as the optic nerve appearance changes as glaucoma progresses. Glaucoma tests are painless and take very little time.

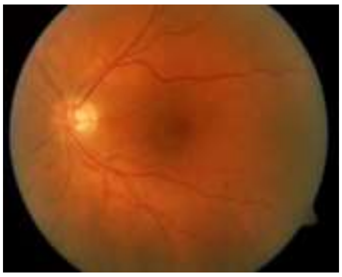

Fig. 5: Normal Image

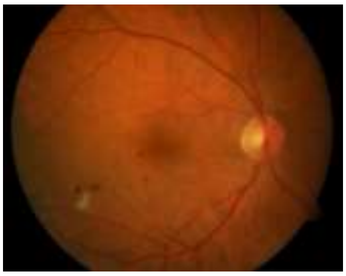

Fig. 6: Abnormal Image

MATERIALS AND METHODS

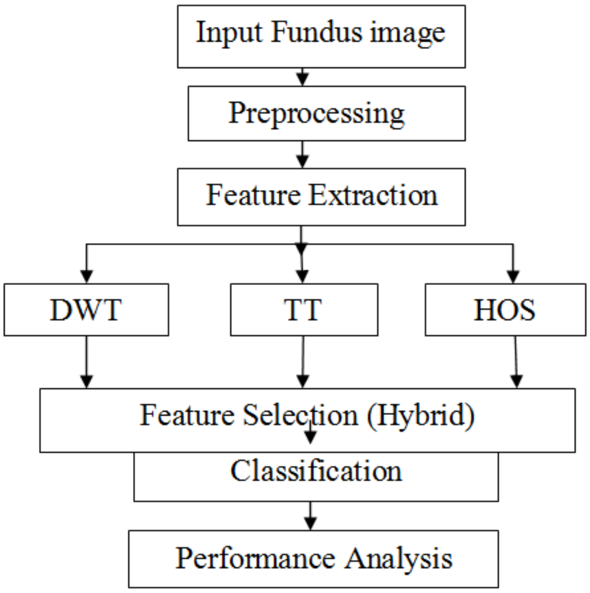

Fig. 7: Block Diagram of Glaucoma Based on Hybrid Features in Retinal Images

Input Image

The input image is the retinal fundus eye image which is RGB image get from the ophthalmologists. The input image taken in the form of JPEG, PNG, or BITMAP format. In a retinal image, the optic disc occupies a small area of the entire retinal image. Retinal images need to be preprocessed before the feature extraction is shown in [Fig.8].

Fig. 8: Input Image

Preprocessing

Preprocessing of retinal images is first step in the automatic diagnosis of retinal disease. The quality of retinal image is not good, so it is necessary to improve the quality of retinal image the purpose of preprocessing is to improve the noisy area from retinal image shown in [Fig.7].

Histogram Equalization

Enhancing the fundus image contrast will aid the feature extraction process. In this work, colored (RGB) eye images are converted to gray scale image by forming weighted sum of R, G, and B.

$$I\ gray=0.2989*R+0.5870*G+0.1140*B$$

After the conversion of gray level, the histogram equalization is done to improve the quality of input images shown in [Fig.9&10].

Preprocessing for Normal Image

Normal Image Input Image Histogram image

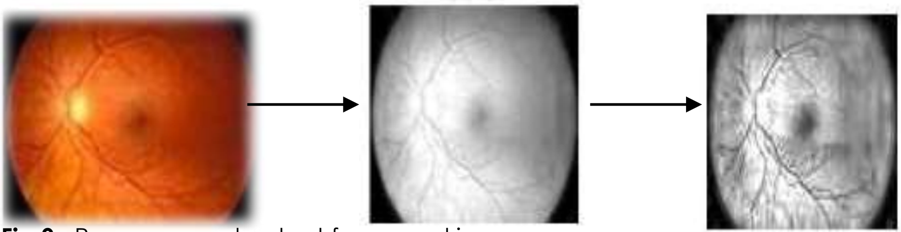

Fig.9: Pre-processed output for normal image

Preprocessing for abnormal Image

Abnormal Image Input Image Histogram image

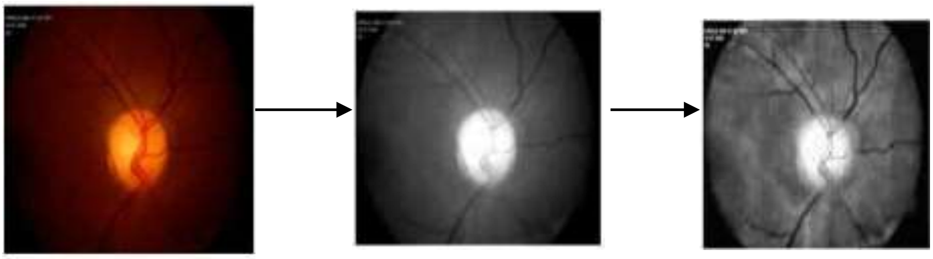

Fig.10: Pre-processed output for abnormal image

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Feature Extraction

Feature extraction is a special form of dimensionality reduction. The purpose of feature extraction is to reduce original data set by measuring certain features that distinguish one region of interest from another. Wavelet based textural features namely energy, entropy, skewness, kurtosis are extracted from retinal images. The analysis and characterization of textures present in the medical images can be done by using the combination of Wavelet Statistical Texture features (WST) obtained from 2-level Discrete Wavelet Transformed (DWT) low and high frequency sub bands. A feature extraction is the determination of a feature or a feature vector from a pattern vector. In order to make pattern processing problems solvable one needs to convert patterns into features, which become condensed representations of patterns, ideally containing only salient information.

Wavelet Based Feature Extraction

A wavelet is a wave-like oscillation that is localized in the sense that it grows from zero, reaches maximum amplitude, and then decreases back to zero amplitude again. It thus has a location where it maximizes, a characteristic oscillation period, and also a scale over which it amplifies and declines. Wavelet analysis developed in the largely mathematical literature in the 1980's and began to be used commonly in geophysics in the 1990's. Wavelets can be used in signal analysis, image processing and data compression. They are useful for sorting out scale information, while still maintaining some degree of time or space locality. Wavelets can be used to compress the information in two-dimensional images from satellites or ground based remote sensing techniques such as radars.

Discrete Wavelet Transform

Discrete wavelet transform (DWT), which transforms a discrete time signal to a discrete wavelet representation, it converts an input series x0, x1,xm, into one high-pass wavelet coefficient series and one low-pass wavelet coefficient series (of length n/2 each) given by:

Where sm (Z) and tm (Z) are called wavelet filters, K is the length of the filter, and i=0,[n/2]-1. Lifting schema of DWT has been recognized as a faster approach.The basic principle is to factorize the poly phase matrix of a wavelet filter into a sequence of alternating upper and lower triangular matrices and a diagonal matrix. This leads to the wavelet implementation by means of banded-matrix multiplications.

Decomposition

Decomposing an image into meaningful components is an important and challenging inverse problem in image processing. A first range of models are denoising models: in such models, the image is assumed to have been corrupted by noise, and the processing purpose is to remove the noise. The decomposition process is mainly used to splitting or segmenting the given images.

Trace Transform

The TT can be defined as a functioning based on T, which is some functional of the image with variable t. T is called the trace functional. In order to define a triple feature, two more functional have been defined and they are designated by P .This is known as the diametrical functional, which is a functional of the TT function when it is considered as a function of the length of the normal to the line only called the circus functional, is a functional operating on the orientation variable, after the previous two operations (T and P) have been performed.

Higher Order Spectra

HOS is a nonlinear method which captures subtle changes in image pixels. The algorithm discussion starts with second order statistics which evaluate both mean value (m) and variance (σ2).

$$Ma = E\{A\} \qquad (3)$$

$$\sigma 2A = E\{(A- Ma)2\} \qquad (4)$$

In addition to these moments, HOS provides higher order moments, i.e., m3;
m4; . . . and nonlinear combinations of the higher order moments called “cumulants",i.e., c1; c2; c3; . . .

Thus, HOS consists of both moment and cumulant spectra.The technique can be used for deterministic and random signals. The so-called “bispectrum", which is a third order statistic, was used in this work. It is obtained by calculating the Fourier transform of the third order correlation of the data:

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B(f1,f2) = E{A(f1) A(f2) A*(f1+ f2)}   (5)

where A(f) is the Fourier is transform of the signal a(nT) and E{.} is an average over an ensemble of random signal realizations. For deterministic signals, the relationship holds without an expectation operation. In this case, the third order correlation is a time-average. For deterministic sampled signals, A(f) is the discrete-time Fourier transform, which, in practice, is computed using the fast Fourier transform (FFT) algorithm. The frequency (f) may be normalized by the Nyquist frequency to be between 0 and 1. In this work, we derived the bispectral phase entropy (Ph), entropy 1 (P1), entropy2 (P2), and entropy 3 (P3). These entropies are similar to the spectral entropy.The equations which govern the phase entropy extraction from HOS parameters.

Scope

In existing method HOS,TT and DWT with SVM classifier only produce a 90% accuracy,87%sensitivity and 90% specificity were achieved. But in this proposed expectation Maximization classifier may produce 95% accuracy,92% sensitivity and 97% specificity.

RESULTS

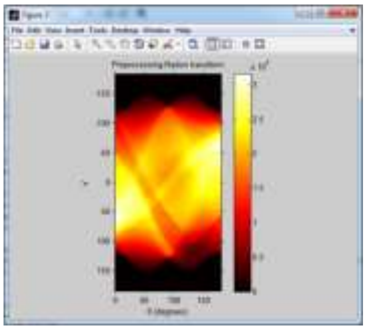
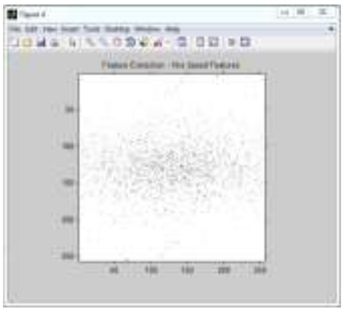


Fig.11: Original Image   **Fig.12:** Histogram Equalization   **Fig.13:** Radon preprocessing Image



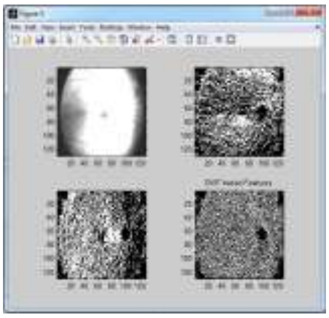


FIG.14: HOS Based Features Image   **FIG.15:** DWT Based Features Image

Take the original image from the fundus camera. Here focussing the retinal area of the eye. Histogram equalization focussed the intensity level of original image. Radon transform also pre-processed in varies degrees of retinal images.HOS is a nonlinear method to captures subtle changes in image pixels shown in fig11- 15. Based on the pixel value calculate the entrophy1, 2, 3 derived. A DWT show varies aspects of features like skewness, kurotis, symlet, and coiflets.

CONCLUSION

An automated system has been successfully developed which is able to detect the glaucoma from the retinal photographs with the performance approaching that of trained clinical observers. It has been found that the glaucoma can be detected irrespective of the stages of its growth. The DWT, TT, HOS based features been employed to detect the complication caused due to glaucoma. This method is found to reduce the manual effort required for the detection and also increase the accuracy when compared to previous method. The performance of the fully automatic system presented here is comparable to medical experts in detecting glaucomatous eyes and it could be used in mass-screenings. The important features automatically identified by the methods also provide a novel representation of the data for the physicians and may help to better understand glaucoma. The detection and classification of glaucoma will done by DWT, TT, HOS transformations. The hybrid feature selection provides a powerful detection and diagnoses the diseases from the retinal images. The extracted hybrid features are fed to Expectation Maximization classifier to find the normal/glaucoma image with high accuracy, sensitivity and specificity. This system can be implemented in hospital to reduce the visual loss by helping the human environment with low cost of finding the glaucoma.

CONFLICT OF INTEREST

There is no conflict of interest.

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FINANCIAL DISCLOSURE

None.

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