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A SURVEY ON AUTOMATIC DETECTION OF RETINAL DISORDERS FROM FUNDUS IMAGES

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Abstract: - A number of retinal disorders are found to be affecting people of all age groups. Various research activities are being carried out to detect these retinal disorders. The image of the retina is captured using a fundus camera. These images are required to be suitable to detect abnormalities. Hence, it is processed in such a way that the unwanted regions are discarded, but there is no major change in the properties of the image. The important features that define the image are extracted and used to classify a retinal image as possessing some abnormality or not. In this work, various methods to detect the different types of retinal disorders such as diabetic retinopathy, hypertensive retinopathy, glaucoma, age-related macular degeneration etc. are discussed.

Keywords: Retinopathy, pre-processing, feature extraction, classification.

1. Introduction

Human eye is an organ which is stimulated by the visible portion of the electromagnetic spectrum and enables vision. The retina is one of the parts at the back of the eye which is photo-sensitive. Photosensitive cells called rods and cones in the retina convert incident light energy into signals that are carried to the brain by the optic nerve which enables us to see. These are the cells responsible for differentiating colors. Damage to the retina leads to vision deterioration and even blindness. Diabetic retinopathy (Fig i) affects people suffering from diabetes. It is characterized by micro-aneurysm, haemorrhage, exudates and neo-vascularization. Hypertensive retinopathy (Fig ii) affects people suffering from high blood pressure [3]. Age-related macular degeneration (Fig iii) is characterized by exudates near the macula. Glaucoma (Fig iv) occurs due to increased pressure of the fluid inside the eye. It can be identified by blood vessel analysis. Retinitis pigmentosa (Fig v) is a disorder in which scars/pigmentation is observed in the retina. This can be detected by texture analysis. Retinoblastoma (Fig vi) is a formation of tumor at the retina. It is usually found in children. Ocular histoplasmosis (Fig vii) is an air-borne disease which can migrate to the eye and cause severe problems. Retinal artery occlusion and retinal vein occlusion are blockage of artery and vein respectively (Fig viii).


Fig i. Diabetic Retinopathy

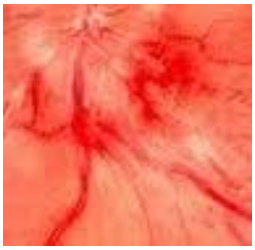
Fig ii. Hypertensive Retinopathy

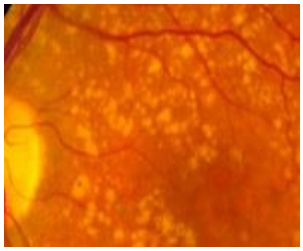
Fig iii. Age-Related Macular Degeneration

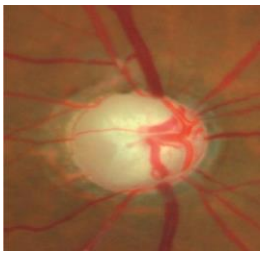
Fig iv. Glaucoma

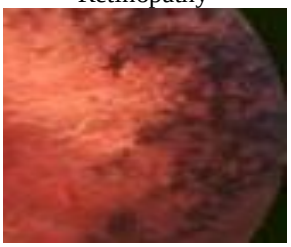
Fig v. Retinitis Pigmentosa

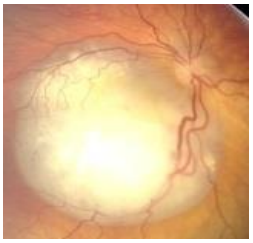
Fig vi. Retinoblastoma


Fig vii. Ocular Histoplasmosis Syndrome


Fig viii. Retinal Vein Occlusion

Retinal disorders are detected using the images that are captured using a fundus camera. The images are thresholded in such a way that only the regions of interest are considered. Features based on shape, texture, brightness etc. are extracted and given to the classifier to classify an image as having a problem such as micro-aneurysm, exudates, haemorrhage.

In section 2, methodology adopted by researchers in previous works is explained. Different disorders that can be detected using already existing methods are also listed. Section 3 includes the methodology and results obtained respectively. The paper is concluded with section 4.

2. Previous Research Activities

There are numerous research work carried out in this field. The basic steps involved are pre-processing, to make the fundus image more suitable for this purpose; feature extraction and classification. Few of the researchers remove the optic disk since it has the same brightness levels as that of exudates.

Pre-processing:

Pre-processing is basically a step that works on improving the current image and making it suitable for further processing. The retinal images captured will contain noise and it might not be clear enough to allow successful detection of disease.

There are various methods involved in making an image suitable for the further steps that need to be carried out for correct detection of the disease.

Green channel extraction:

The retinal images captured are in the RGB color space. Since the green color has more intensity than red and blue, it is better to extract only the green channel [5].

Transforming color space:

Some of the automatic detection uses images of the RGB model. But certain works carried out for the same purpose transform RGB model to a more suitable model. The different color space/models are:

RGB: a model where the primary colors red, green and blue are added to form various colors.

YIQ: here, Y stands for luminance information; I and Q mean in-phase and quadrature respectively.

HSI: this is a color representation system that concentrates on hue, saturation and intensity.

LAB: L refers to lightness and 'a' and 'b' are the two channels.

Sopharak et al, 2010 [2] convert RGB to grayscale by taking average of red, green and blue channels, and the median filtering is performed to remove noise. Sundararaj Wilfred Franklin et al, 2013 [6] transformed the image to LAB color space. Haniza Yazid et al, 2010 [7] YIQ space, converted RGB to YIQ space. Mohd Hanafi Ahmad Hijazi et al, 2013 [9] use both RGB and HSI color space.

Contrast enhancement:

This is a step that is used to enhance the contrast of image features. The blood vessels need to be enhanced since the presence of abnormal blood vessels can indicate serious case of neo-vascularization.

Removal of optic disk:

Optic disk is a bright region in the eye opposite to the retina. Since the intensity of this region is very high, it often gets mistaken as flash or exudates by automatic detection systems. Hence, it is important to eliminate this area. Some studies do not eliminate flash.

Feature extraction:

A set of features that may contain relevant information are extracted from the input file. These features are used by the further processes in order to perform the desired task. Features that are extracted are based on shape, texture, brightness. Better results can be obtained when the relevant features are used. Shape, size and area of the retina affected by the exudates and haemorrhage are used often. Textural features such as color components, standard deviation, mean, median, variance of the pixels are also used. To detect abnormalities like neo-vascularization, edge detection is important.

Classifiers used:

The features extracted in the previous step are fed into a classifier. It is also fed with a training dataset. Various classifiers could be used to differentiate the normal retinal images from those containing certain abnormalities. K-nearest neighbor classifier, Naïve Bayesian, SVM classifiers, neural network classifier and fuzzy C-means classifier have been used either separately or in combination with other classifiers.

Database used:

Publicly available databases are used to measure the efficiency of the methods proposed by various researchers. DIARETDB0, DIARETDB1 are the databases created by a group of researchers from Finland. They contain 130 and 89 images respectively where few of the images contain irregularities related to diabetic retinopathy such as exudates and hemorrhages, and the rest are normal. Few other databases such as DRIVE, STARE, Messidor are also used by researchers.

Fatma Demirezen Yagmur et al, 2008 [3] show the detection of Diabetic Retinopathy, Hypertensive retinopathy, Macular Degeneration, Vein Branch Occlusion, Vitreous hemorrhage.

Manjiri B. Patwari et al, 2013 [5] show methods to sharpen the blood vessels. This can be used to identify neo-vascularization. Diseases which can be detected by this are diabetic retinopathy, glaucoma, ocular histo-plasmosis syndrome, retinal vein occlusion, retinal artery occlusion and hypertensive retinopathy.

Sundararaj Wilfred Franklin et al, 2013 [6] developed the system to diagnose diabetic retinopathy; it can also be used to detect other retinal disorders where exudates detection is a primary function such as hypertensive retinopathy, age-related macular degeneration and macular edema. Retinoblastoma can also be detected using exudates detection methods.

Carla Agurto et al, 2014 [13] talk about detection of hypertensive retinopathy. Since it uses artery and vein features, it can be used to identify retinal vein occlusion and retinal artery occlusion.

Veronika Kurilová et al, 2015 [14] compares two approaches used to extract blood vessels with morphological operations. The fundus camera images are pre-processed by performing morphological operations on the green channel. Both the approaches use White Top Hat transform to extract bright features and Black Top Hat transform to extract dark features. In approach 1, morphological closing is performed with a structural element disc of radius 10 pixels. This is added to the green channel extracted image with increased contrast. Morphological opening is performed with disc structural element of radius 4 pixels, in order to remove small regions. Blood vessels and background is separated by adjusting intensity and finally a binary mask is created to mark blood vessels clearly on green channel image and disc structural element of radius 2 pixels was applied in order to remove small parts that were not connected to the blood vessels. Applying different structural elements could enhance different characteristics of the image but the negative aspect was that some important artifacts were being suppressed. So, the new approach the pre-processed image was processed using structural element on two different channels and the results were combined.

V. Vijaya Kumari et al, 2010 [15] Blood vessels of different thickness are extracted using morphological open and close. Exudates are detected using by using open and close operations of different sizes. The optic disk is finally obtained by subtracting these two images, and by using the concept of convergence of blood vessels.

3. Results

Specificity, sensitivity and accuracy are calculated. Sensitivity is defined in medical field as the proportion of patients with the disease having positive test result. Specificity is defined as proportion of patients who do not have a disease and get negative result. These values are defined by the formula given below [6] :

$$Sensitivity = \frac{TP}{TP + FN}$$

$$Specificity = \frac{TN}{TN + FP}$$

$$Accuracy = \frac{TP + TN}{TP + FP + TN + FN}$$

Predictive value is defined as probability of pixels that are classified as problematic and they are actually problematic [6].

$$Predictive\ Value = \frac{TP}{TP + FP}$$

Table 1: Methodology adopted and results obtained in earlier research activities

Sl. No	Paper	Methodology Adopted	Results Observed
1	Edge Sharpening for Diabetic Retinopathy Detection by Haniza Yazid [7] in IEEE 2010	a) Convert RGB image to YIQ space, extract red, blue, green component b) Segmentation and edge sharpening through ramp width reduction (2steps) c) Classification could be performed using hidden markov model, Bayesian or neural networks	Images showing edges before and after sharpening. Classification was under development.

2	Automatic Detection of Red Lesions in Digital Color Fundus Photographs by Meindert Neimeijer, May2005, IEEE Transaction in Medical Imaging [1]	Extract candidate objects from shade corrected image Using a set of 68 features, classified with k-nearest neighbor classifier	Specificity 87% Sensitivity 100%
3	Calculation of Retinal Blood vessels Tortuosity by using Image processing Techniques and Statistical Techniques by Manjiri Patwari published in 2nd International Conference on System Modeling & Advancement in Research Trends (SMART) 2013 [5]	Green channel extraction from RGB image. Complement function to enhance blood vessels, histogram equalization to enhance the image. Morphological (dilation and erosion) to enhance the blood vessel. 2D median filtering for highlighting and removing noise from open function. Threshold function to extract the blood vessel.	Specificity 0 for all databases, Saswade database – 96%accuracy, 0.92 sensitivity. Diaretdb0 – 95% accuracy, 0.95 sensitivity Diaretdb1 – 96% accuracy and 0.96 sensitivity DRIVE – 98% accuracy, 0.98 sensitivity
4	Diagnosis of diabetic retinopathy by employing image processing technique to detect exudates in retinal images by Sundararaj Wilfred Franklin in IET Image Processing 2014 [6]	Transform RGB to Lab color space, replace luminosity with processed data and convert back to RGB. Apply mean filtering. Contrast limited adaptive histogram equalization is applied. Extract features such as color, size, texture, shape, edge strength. Classification using multilayer perceptron neural network.	Accuracy 99.7% Specificity 99.8% Sensitivity 96.3%
5	Diabetic Retinopathy Screening Using Computer Vision by Christopher E. Hann in Proceedings of the 7th IFAC Symposium on Modeling and Control in Biomedical Systems, Aalborg, Denmark 2009 [4]	*Identifying hard exudates* : Define optic disk, find exudates using median filter, add pixels and confirm bright exudates, remove false exudates, output number and sizes of all exudates	Sensitivity 94.9% Specificity 96.7% PPV 0.95 NPV 0.97
		Identifying dot haemorrhages: Create binary image, Select potential DHs by shape, Check if potential DHs are blood vessels, Remove false DH, Output number and size of all DH.	Sensitivity 98.7% Specificity 100% PPV 0.96 NPV 1
6	Image Processing for Identifying Different Stages of Diabetic Retinopathy by R. Manjula Sri in International Journal of Recent Trends in Engineering & Technology [8]	Green plane extraction: RGB to grayscale. Edge detection using non-linear filter. Morphological processing to estimate area and perimeter	Accuracy 85%

7	Automatic Recognition of Retinopathy Diseases by Using Wavelet Based Neural Network by Fatma Demirezen for IEEE 2008 [3]	Resize the image, transform to grayscale, and find wavelet coefficient using matlab wavelet toolbox. Wavelet features are input to the neural network classifier	Average recognition rates for HR is 50%, DR is 90%, vitre interior haemorrhage is 93%, ARMD is 95%, Inferior vein branch lock is 70%
8	Automated System for the Detection of Hypertensive Retinopathy by Sarmad Khitran for Image Processing Theory, Tools and Applications (IEEE) 2014 [11]	Background is separated from foreground using mean and variance based methods. Blood vessel extraction using Gabor wavelet	Accuracy 96.5 % for VICAVR and 98% for DRIVE database.
9	Classification of Retinal Image for Automatic Cataract Detection by Meimei Yang for IEEE 15th conference on e-Health Networking, Applications and Services 2013 [12]	Extract G channel, luminance, top-bottom hat transformation, features such as luminance, gray and gradient vectors. Neural network classifier	True positive rate : 82%
10	Retinal Blood Vessels Extraction Using Morphological Operations by Veronika Kurilová, Jarmila Pavlovičová , 2015	Comparison of two methods for blood vessel extraction. Messidor database is used.	Both the approaches give almost similar specificity, sensitivity and accuracy.

4. Conclusion

The various retinal disorders are detected from images captured using fundus cameras. The images go through pre-processing, feature extraction and classification stages. Images are pre-processed in order to make it suitable for extracting the features. The extracted features are then passed to a classifier that is observed to be appropriate. The sensitivity, specificity and/or accuracy are evaluated.

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