Optometry-For automatic detection of eye diseases at an early stage

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Abstract:
Optometry deals with the application of image processing techniques for automatic detection of eye diseases. The paper deals with the detection of ophthalmic diseases like Diabetic Retinopathy (DR), Glaucoma and Age related Macular Degeneration (ARMD). DR is the major cause of blindness among adults and occurs when the increased glucose level in the blood damages the capillaries, which nourish the retina. The severity of the disease is measured as mild, moderate and severe in non-proliferative condition. Glaucoma is a pathological condition of optic nerve damage caused by an increase in intraocular pressure within eye. Age-related macular degeneration (ARMD) the leading cause of worldwide blindness in the elderly age is a bilateral ocular condition that affects the central area of retina known as the macula. The main objective is to provide the application to the patients in rural areas at a very low cost and instrumentation.

Index Terms— *Active contours, Angle calculation, AOD-500 (Angle open distance), Apex point determination, masking, Exudates, Fundus image, Drusen, Macular Degeneration.*

1. INTRODUCTION:

Retinal analysis is a non intrusive diagnosis method in modern ophthalmology. With the application of image processing techniques, the eye diseases are detected at a very early stage. Some of the image processing techniques are image extraction, pattern matching, image fusion, segmentation etc. In developing and under developing countries large a number of people are suffering from ophthalmic diseases like Diabetic Retinopathy (DR), Glaucoma and Age related Macular Degeneration (ARMD). Diabetes mellitus often results in Diabetic Retinopathy which is caused by pathological c-hanges of the blood vessels which nourish the retina. DR is the major cause of blindness among adults and occurs when the increased glucose level in the blood damages the capillaries, which nourish the retina. Glaucoma is a pathological condition of optic nerve damage which comes along with an ongoing destruction of optic nerve head (ONH) caused by an increase in intraocular pressure within eye. Due to damage to large number of nerve fibres, a blind spot is created leading to loss of vision. Age-related macular degeneration (ARMD) the leading cause of worldwide blindness in the elderly age is a bilateral ocular condition that affects the central area of retina known as the macula. Detection of ARMD is done by using Neural Network Analysis (NNA) method and the two classes of Age-related macular degeneration (dry or wet ARMD), one of which is dry macular can be further classified into three classes early ,intermediate and advanced as a measure of severity.

2. LITERATURE REVIEW :

2.1 DIABETIC RETINOPATHY:

The detection of exudates in retinal images was investigated by many researchers as follows:

A tool to segment the retinal images using Fuzzy CMeans (FCM) clustering technique was developed. The features are extracted

and ranked using Genetic Algorithm and classified using neural network. [3].

All Exudates from nonmydriatic, were detected from low contrast retinal digital images using mathematical morphology techniques. An automatic method for detection of exudates from the diabetic retinopathy images using fuzzy c-means clustering technique was also proposed. [2].

A segmentation method was used to differentiate the contrast in larger and thin blood vessels. Adaptive local thresholding is used to produce the normalized image and to extract larger vessels. Thin vessel segments are classified using Support Vector Machine. Different stages of Diabetic retinopathy disease severity are detected by Morphological operation and Texture Analysis methods applied on retinal images was found by The statistical features are extracted and classified using Bayes Minimum Distant Discriminant (MDD) classifier and the classifier is compared with original and brightness enhanced image [6].

2.2 Glaucoma:

The following are some of the reference papers which were used for developing the Glaucoma project module.

Methods were developed which are used to detect main features of retinal fundus images such as optic disk, fovea, and exudates and blood vessels using different techniques. To determine the optic Disk and its centre Author find the brightest part of the fundus and apply Hough transform[5]. Validation of Retinal Image Registration Algorithms by a Projective Imaging Distortion Model. A variety of methods for retinal image registration have been proposed. Authors also present the validation tool for any retinal image registration method by tracing back the distortion path and accessing the geometric misalignment from the coordinate system of reference standard[8].

Automated localization of retinal optic disk using hough transform- The retinal fundus image is widely used in the diagnosis and treatment of various eye diseases such as diabetic retinopathy and glaucoma. The proposed methodology consists of two steps: in the first step, region of interest (ROI) is found by image by means of morphological processing, and in the second step, optic disk is detected using the Hough transform.[7].

2.3 Age Related Macular Degeneration (ARMD):

Some of the references for ARMD was done from the following papers:

Bayesian Network Classifier Local histogram based feature vectors 140 volumetric OCT images(68 normal, 72 ARMD effected) Area Under the Receiver Operating Curve (AUC) 94.4%, accuracy[1].

CAPT study consisting of 50 stereoscopic color fundus images, and Amish study consisting 88 color fundus Photographs (CFP's) Accuracy/ Specificity/Sensitivity :for CAPT CFP's 0.82,0.75,0.82), for Amish CFP's (0.86,0.71,0.85) [4]

Histogram Based Adaptive Local Thresholding Morphological Features (size, area, and number) of macular region 349 (IRIDEX Corporation, Mountain View, CA) fundus images Precision/accuracy was developed[9].

3. MATERIALS AND METHODS:

3.1 DIABETIC RETINOPATHY:

3.1.1Workflow for diabetic retinopathy:

The complete workflow in order to determine the severity of the disease is described below:

Pre- processing: Image pre-processing is the initial step in automated retinal pathology diagnosis. It includes techniques such as contrast enhancement, gray/green component, image denoising, etc. In case of Gray scale image, the intensity value represents height above a base plane. Thus,

the Gray scale image represents a surface in three dimensional Euclidean space.

Feature Extraction: The features such as blood vessels, exudates and optic discs are extracted for further analysis. In this extraction process the morphological operations such as opening, closing, erode and dilate are used. This image is converted

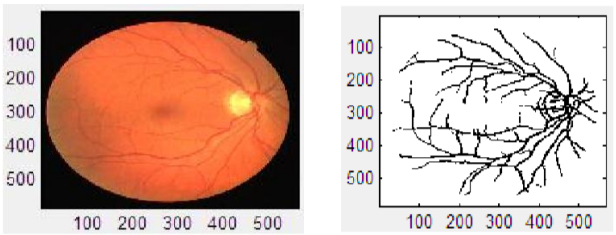

Figure 3.2 Blood vessels extraction

into a binary image. Figure 3.2 shows the extracted blood vessels from an input image.

Exudates: Exudates are one of the early occurring lesions shown in figure 3.3.

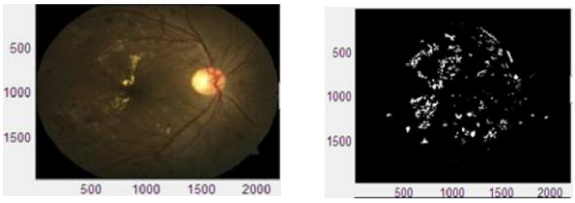

Figure 3.3 Exudates extraction

Optic disc: The image is filtered in order to eliminate large gray level variations within the papillary region. The vessels are filled applying a simple Closing operation. The optic disc extracted is as shown in figure 3.4

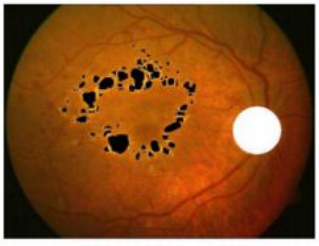

Figure 3.4: Optic Disc extraction

Disease severity: The severity of the disease is measured depending on the area of the exudates calculated after pre-processing and feature extraction. Depending on the severity, there are three categories such as mild, moderate and severe stage.

3.2 GLAUCOMA:

3.2.1 WORKFLOW FOR DETECTION OF GLAUCOMA:

To detect the presence or absence of glaucoma the angle from the apex point and the optic disc has to be calculated, after performing certain processing of image. The workflow for glaucoma is defined further.

Segmentation: Image segmentation is one of the most important steps leading to the analysis of processed image data the main goal is to divide an image into parts that have a strong correlation with objects or areas of the real world contained in the image .The aim is to complete segmentation, which results in a set of disjoint regions corresponding uniquely with objects in the input image, or for partial segmentation, in which regions do not corresponds directly with image objects.

Apex Point: The field of mathematical morphology contributes a wide range of operators to image processing, all based around a few simple mathematical concepts from set theory. The operators are particularly useful for the analysis of binary images and common usages include edge detection, noise removal, image enhancement and image segmentation. The two most basic operations in mathematical morphology are erosion and dilation. Both of these operators take two pieces of data as input: an image to be eroded or dilated, and a structuring element (also known as a kernel). The two pieces of input data are each treated as representing sets of coordinates in a way that is slightly different for in binary and grayscale images. In this object, image erosion is of interest.

Masking: Using (Xref, Yref) as the reference point in the original image, a 50x50 square mask is to be created around the image. This is primarily done because; the region of interest is the anterior chamber just to its apex point, to avoid spurious layers interfering with the AOD 500 determination. Once the masking square is set, the image is to be processed again in order to obtain the approximate angle of the anterior chamber apex. The following image (figure 3.6) shows the masked image.

Figure 3.6: Masked image

Angle Calculation: The Ultrasound Bio-microscopy (UBM) images resolution reveal that distance between 2 pixels is approximately equal to 19.52 µm. Hence in order to calculate the Angle Open Distance 500 µm, it is necessary to move a distance of approximately 500 µm (approx 25 pixels) from the apex of the masked anterior chamber along its edges. From here, a perpendicular line to the virtual reference line is to be projected to calculate AOD using analytical geometry concepts as shown in figure 3.7. From the point of intersection of the perpendicular to the virtual line, another perpendicular to the other saddle edge is to be drawn .Let the two angles be θ1 and θ2. So the effective angle in radians will be θ = θ1+θ2 or θ = θ1-θ2 depending upon the position of θ2, whether it is above or below the line L3.

After finding θ, the diagnosis of the eye can be determined by comparing it with a threshold angle (θC). If the θ is found to be

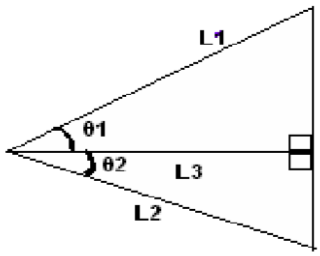

Figure 3.7: Angle calculation

greater than θC, the eye is diagnosed as normal eye; otherwise, it is diagnosed to be diseased eye. In this Project, a Fundus Image is taken as input image. Image Segmentation is applied on the fundus image. After segmenting the image, binary image is obtained by contouring the image. Region of Interest is extracted from the contoured image. The remaining area is masked and angle is calculated from the apex point. If the angle is below 20 degrees glaucoma is observed.

3.3. AGE RELATED MACULAR DEGENERATION:

3.3.1WORKFLOW FOR DETECTION OF ARMD:

The workflow for Age related macular degeneration consists of the following modules:

1)**Preprocessing and contrast enhancement:**

In order to improve quality, retinal image preprocessing is performed to remove the noisy area from the retinal image. This is required for the reliable extraction of features and abnormalities as feature extraction and abnormality detection algorithms give poor results in the presence of noisy background. First, the green

component is extracted from the colored retinal image. After the green component extraction, histogram equalization is used to enhance the contrast and improve the quality of the retinal image. Finally an-isotropic diffusion is applied to remove the noise from the image.

2) **Locating anatomic structure**:

Since image contains many other structures too like blood vessels based on segmentation of vascular arcades. Detection of the anatomic structure is the characterization of the normal or affected state that exists in retina. The algorithm is based on mathematical morphology and curvature evaluation for the detection of vessel like patterns in a noisy environment.

3) **Detect bright lesions:**

Vessels like patterns are bright features defined by morphological properties like linearity, connectivity, width, and by a specific Gaussian like profile whose curvatures vary smoothly along the vessels. Since drusen are bright lesion, therefore other dark regions are covered up using morphological closing so that bright regions get highlighted. Outcome of this process is a smooth image which contained candidate regions.

4) **Feature set extraction:**

After applying preprocessing techniques like histogram equalization a better contrast image is obtained. Feature extraction can be done in two steps:

A. Feature detecting optic nerve

i. Vessel Density: Vessel density is defined as the number of vessels existing in a unit area of the retina. Since the vasculature that feeds the retina enters the eye, the vessels tend to be most dense in this region. ii. Average Vessel Thickness: Vessels are also observed to be thickest near the optic nerve since most branching of both the arterial and venous structure does not take place until the tree is more distal from the optic nerve.

B. **Feature detecting disease**

Some of the features that are extracted for detecting disease are given blow: i. Area ii. Radius iii. Perimeter iv. Mean v. Standard Deviation vi. Variance vii. Entropy. The entropy is a statistical measure of randomness that can be used to characterize the textural feature of the input image.

5) Screening classification process

Neural Network Analysis (NNA) has been used in different ways in medical field. The principle advantage of NNA is to generalize, adapting to signal distortion and noise without the loss of robustness. Neural network analysis have the same number of neurons in input and output layers and less in the hidden layers. The network is trained using the input vector itself as the desired output. Each auto associative network is trained independently for each class using feature vector of the class. The squared error between an input and the output is generally minimized by the network of the class to which the input pattern belongs. This property of NNA enables the classification of an unknown input pattern. The unknown pattern is fed to all the networks and is classified to the class with minimum squared error.

4.RESULTS :

The overall results can be given by detecting the presence/severity of each disease for a single input fundus image. Once the image is selected the output screen after the required processing is displayed as shown in figure 4.2. It displays the severity/presence of diseases along with the processed images for each module.

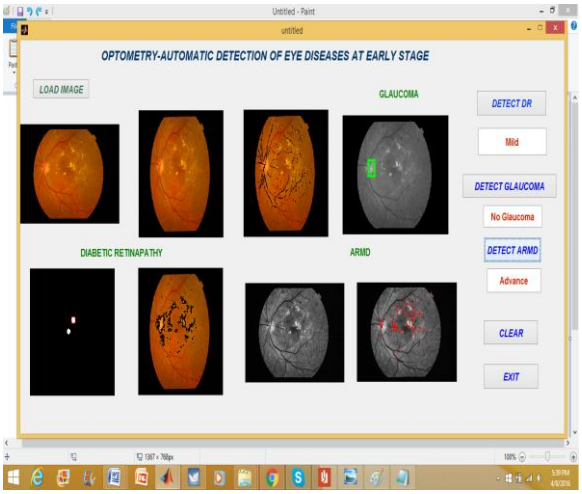

Figure 4.2 Overall output

5. CONCLUSIONS :

The potentials of Optometry- Detection of eye diseases at early stage has been briefly given in this project. It mainly deals with three eye diseases Diabetic Retinopathy, Glaucoma and Age Related Macular Degeneration. Diabetic Retinopathy is caused by pathological changes of the blood vessels which nourish the retina. Features like blood vessels, optic disc and exudates have been extracted by using image processing techniques like segmentation, histogram equalization and hough transforms. Glaucoma is a pathological condition of optic nerve damage which comes along with an ongoing destruction of optic nerve head (ONH) caused by an increase in intraocular pressure within eye. Due to damage to large number of nerve fibers, a blind spot is created leading to loss of vision. Detection of the presence of glaucoma by taking an input fundus image and applying morphological operations and sussman method has been done. Age-related macular degeneration (ARMD), is a bilateral ocular condition that affects the central area of retina known as the macula. Detection of ARMD has been done by using Neural Network Analysis method. The bright lesions are extracted by the means of anisotropic diffusion. DR completed by detecting the severity of the disease as mild, moderate, severe in non- proliferative and proliferative conditions. In Glaucoma, the region of interest is extracted and angle from the apex point and optic disc is calculated to check whether glaucoma is present or not. In age related macular degeneration (ARMD), the severity of the disease is measured as early, mild or advanced. These techniques and analysis not only helps to diagnose the disease but also helps detecting the severity of the disease at an early stage. Taking the images, detecting the disease at very low cost and applying instrumentation techniques makes it easy for the patients in rural and urban areas.

7.REFERENCES:

[1] Albarrak et al 2013 Bayesian Network Classifier Local histogram based feature vectors 140 volumetric OCT images(68 normal, 72 ARMD effected) Area Under the Receiver Operating Curve (AUC) 94.4%, accuracy.

[2] Akara Sopharak detected exudates from non-mydriatic, low contrast retinal digital images using mathematical morphology techniques. Akara Sopharak proposed an automatic method for detection of exudates from the diabetic retinopathy images using fuzzy c-means clustering technique.

[3] Alireza Osareh developed a tool to segment the retinal images using Fuzzy CMeans (FCM) clustering technique. The features are extracted and ranked using Genetic Algorithm and classified using neural network.

[4] CAPT study consisting of 50 stereoscopic color fundus images, and Amish study consisting 88 color fundus Photographs (CFP's) Accuracy/ Specificity/Sensitivity :for CAPT CFP's 0.82,0.75,0.82), for Amish CFP's (0.86,0.71,0.85)

[5] Kevin Noronha performed a work, "Enhancement of retinal fundus Image to highlight the features for detection of abnormal eyes". This work specifies the methods used to detect main features of retinal fundus images such as optic disk, fovea, and exudates and blood vessels using different techniques. To determine the optic Disk and its centre Author find the brightest part of the fundus and apply Hough transform.

[6] Lili Xu used a segmentation method to differentiate the contrast in larger and thin blood vessels. Adaptive local thresholding is used to produce the normalized image and to extract larger vessels. Thin vessel segments are classified using Support Vector Machine. Different stages of Diabetic retinopathy disease severity are detected by Morphological operation and Texture Analysis methods applied on retinal images was found by The statistical features are extracted and classified using Bayes Minimum Distant

Discriminant (MDD) classifier and the classifier is compared with original and brightness enhanced image .

[7] S. Sekhar performed a work," Automated localization of retinal optic disk using hough transform". The retinal fundus image is widely used in the diagnosis and treatment of various eye diseases such as diabetic retinopathy and glaucoma. The proposed methodology consists of two steps: in the first step, region of interest (ROI) is found by image by means of morphological processing, and in the second step, optic disk is detected using the Hough transform.

[8] Sangyeol Lee performed a work, "Validation of Retinal Image Registration Algorithms by a Projective Imaging Distortion Model. A variety of methods for retinal image registration have been proposed. Authors also present the validation tool for any retinal image registration method by tracing back the distortion path and accessing the geometric misalignment from the coordinate system of reference standard.

[9] Thomas R. Friberg et al 2007 Histogram Based Adaptive Local Thresholding Morphological Features (size, area, and number) of macular region 349 (IRIDEX Corporation, Mountain View, CA) fundus images Precision/accuracy.