IMPLEMENTATION OF A CONSPICUOUS RETINAL IMAGE ANALYZER FOR DIABETIC RETINOPATHY

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Abstract: In the recent years, automated retinal image analysis has become a large field of research due to advances in computer vision techniques, and image acquisition has opened exciting possibilities to study the pathogenesis of a number of diseases. Most of the recent studies focused over the association of retinal calibers to diagnose different types of subclinical diseases like atherosclerosis, hypercholesterolemia, inflammation and endothelial dysfunction, as well as clinical cardiovascular diseases, such as arterial hypertension, diabetes mellitus, diabetic retinopathy, stroke, kidney and heart diseases. Due to these significant advances with retinal image analysis, the recent research focused mostly towards the better analysis of retinal images to get more accurate analytical results in the detection of different diseases. Among the related eye diseases, Diabetic Retinopathy is the most chronic disease which affects nearly one out of every ten persons with diabetes, according to point prevalence estimates. Diabetic Retinopathy is one of the most important reasons which make the key cause of vision loss, especially in the middle-aged people. Hence there is a need of early diagnosis to prevent the eyes from permanent vision loss which was the more severe damage at advanced stage. However due to the increasing population, the manual diagnosis of retina images results in an extra manual effort, which forces to develop an automatic Diabetic Retinopathy screening system based on the retinal image analysis.

Keywords: Diabetic Retinopathy, Segmentation

1. Introduction

Retinal image analysis is an active research in recent years. This provides better understanding for the diagnosis of several eye related diseases like glaucoma. Among the related eye diseases, DR is the most chronic disease which affects nearly one out of every ten persons with diabetes, according to point prevalence estimates. According to recent survey [1], 4% of the country population has been diagnosed of diabetes disease alone and it has been recognize and accepted as one of the main cause of blindness in the country if not properly treated and managed. Early detection and diagnosis have been identified as one of the way to achieve a reduction in the percentage of visual impairment caused by diabetes with more emphasis on routine medical check which the use of special facilities for detection and monitoring of the said disease [1]. The effect of this on the medical personnel need not be overemphasized. It has lead to increase work load on the personnel and the facilities, increase in diabetes screening activities just to mention a few. A lot of approaches have been suggested and identified as means of reducing the stress caused by this constant checkup and screening related activities among which is the use medical digital image signal processing for diagnosis of diabetes related disease like diabetic retinopathy using images of the retina.

Diabetes is a disorder of metabolism. The energy required by the body is obtained from glucose which is produced as a result of food digestion. Digested food enters the body stream with the aid of a hormone called insulin which is produced by the pancreas, an organ that lies near the stomach. During eating, the pancreas automatically produces the correct amount of insulin needed for allowing glucose absorption from the blood into the cells. In individuals with diabetes, the pancreas either produces too little or no insulin or the cells do not react properly to the insulin that is produced. The buildup of glucose in the blood, overflows into the urine and then passes out of the body. Therefore, the body loses its main source of fuel even though the blood contains large amounts of glucose [2].

Basically there are three types of diabetes, Type 1 Diabetes, is caused as a result of auto immune problem. The immune system of the body destroys the insulin producing beta cells in the pancreas leading to no or less production of the required insulin by the pancreas. Type 2 Diabetes is a result of malfunctioning of the beta cell itself. This malfunction includes non-production of insulin or a situation known as insulin resistance. In insulin resistance, the muscles, fat and other cells do not respond to the insulin produced. Type 3 is known as gestational diabetes and only occurs during pregnancy. During this stage, the body resists the effect of insulin produced.

The effect of diabetes on the eye is called Diabetic Retinopathy (DR). It is known to damage the small blood vessel of the retina and this might lead to loss of vision. The disease is classified into three stages viz: Background Diabetic Retinopathy (BDR), Proliferate Diabetic Retinopathy (PDR) and Severe Diabetic Retinopathy (SDR). In BDR phase, the arteries in the retina become weakened and leak, forming small, don’t like hemorrhages. These leaking vessels often lead to swelling or edema in the retina and decreased vision. In the PDR phase, circulation problems cause areas of the retina to become oxygen-deprived or ischemic. New fragile, vessels develop as the circulatory system attempts to maintain adequate oxygen levels within the retina. This phenomenon is called neo-vascularization. Blood may leak into the retina and vitreous, causing spots or floaters, along with decreased vision. In the SDR phase of the disease, there is continued abnormal vessel growth and scar tissue, which may cause serious problems such as retinal detachment and glaucoma and gradual loss of vision.
1.1 Abnormalities Associated with the eye.

Abnormalities associated with the eye can be divided into two main classes, the first being diabetes disease of the eye, such as cataract, conjunctivitis, blepharitis and glaucoma. The second group is categorized as life style related disease such as hypertension, arteriosclerosis and diabetes [6]. When the retina is been affected as a result of diabetes, this type of disease is called Diabetic Retinopathy (DR), if not properly treated it might eventually lead to loss of vision. Ophthalmologists have come to agree that early detection and treatment is the best treatment for this disease [1]. DR occurrence have been generally categorized into three main form viz, BDR, PDR, SDR. These were explained in chapter one of this report. These Three classes can occur in any of the form described below as related to this research work.

**Microaneurysms:** These are the first clinical abnormality to be noticed in the eye. They may appear in isolation or in clusters as tiny, dark red spots or looking like tiny hemorrhages within the light sensitive retina. Their sizes ranges from 10-100 microns i.e. less than 1/12th the diameter of an average optics disc and are circular in shape [7], at this stage, the disease is not eye threatening.

**Hemorrhages:** Occurs in the deeper layers of the retina and are often called ‘blot' hemorrhages because of their round shape.

**Hard exudates:** These are one of the main characteristics of diabetic retinopathy and can vary in size from tiny specks to large patches with clear edges. As well as blood, fluid that is rich in fat and protein is contained in the eye and this is what leaks out to form the exudates. These can impair vision by preventing light from reaching the retina.

**Soft exudates:** These are often called ‘cotton wool spots’ and are more often seen in advanced retinopathy.

**Neovascularization:** This can be described as abnormal growth of blood vessels in areas of the eye including the retina and is associated with vision loss. This occurs in response to ischemia, or diminished blood flow to ocular tissues. If these abnormal blood vessels grow around the pupil, glaucoma can result from the increasing pressure within the eye. These new blood vessels have weaker walls and may break and bleed, or cause scar tissue to grow that can pull the retina away from the back of the eye. When the retina is pulled away it is called a retinal detachment and if left untreated, a retinal detachment can cause severe vision loss, including blindness. Leaking blood can cloud the vitreous (the clear, jelly-like substance that fills the eye) and block the light passing through the pupil to the retina, causing blurred and distorted images. In more advanced proliferate retinopathy; diabetic fibrous or scar tissue can form on the retina [8].

Diabetic retinopathy causes changes in the retina, which is the most important tissue of the eye [13]. An analogy between the eye and a camera could be presented to illustrate the importance of the retina: if an eye is considered as a camera, the retina is the film of the camera that catches an image from the target [13]. There may exist different kinds of abnormal lesions caused by diabetic retinopathy in a diabetic’s eye. In this master’s thesis the following lesion types are briefly described: microaneurysm, hard exudates, soft exudates, hemorrhage, and revascularization. The features of different abnormal lesion types are shown in Table 1.

**Microaneurysms** are the earliest clinically detectable lesions [3], [13], [14], and thus it’s important to have a method for detecting Microaneurysms so that incipient retinopathy may be noticed in its early stages. Microaneurysms are local distensions of retina capillary [14]. These outpuncting of capillary walls can be seen as tiny, round dots [3]. Figure 1.3(a) shows a microaneurysm marked with an arrow. The image is magnified, but it is still difficult to distinguish the microaneurysms due to its small size. When Microaneurysms are coated with blood, they may be indistinguishable from dot hemorrhages [3]. Thus, the term “red small dot” is used in this master’s thesis to cover both Microaneurysms and small dot hemorrhages. Microaneurysms are not necessarily permanent changes, but they may first appear and then disappear during some period of time [13], [14]. Intra-retinal hemorrhages appear when capillaries or Microaneurysm rupture [17] and some blood leaks out of the vessels.

Hemorrhages can be seen as red, dot-blot or flame shaped regions [3]. A fundus with multiple hemorrhages is shown in Figure 1.3(b). Hard exudates are accumulated lipid formations leaked from weakened vessels [13], [17]. Hard exudates lesions are waxy and yellow with relatively clear edges [3]. Hard exudates often appear in clusters or rings [3]. Figure 1.3(c) represents a fundus where multiple hardexudates appear as bright lesions.

Soft exudates, also called cotton wool spots or micro-infarctions, appear when terminal retinal arterioles are obstructed [17], [13]. Soft exudates are small, whitish lesions with blurry edges [3]. Figure 1.3(d) shows a magnified fundus image where a soft exudates lesion is marked with an arrow. As seen in the figure, soft exudates are not usually as visible as hard exudates. Extensive lack of oxygen caused by obstructions may lead to development of new blood vessels that are weak and can therefore easily tear [14], [18], [13], [17].

The diseases where new blood vessels appear is called Neovascularization. Neovascularization is the most serious abnormality type in diabetic retinopathy since profuse bleeding may produce loss of vision [18]. Figure 1.3(e) shows a fundus with neovascularization. New small vessels have appeared on the optic disk that is marked with an arrow in the image. The other arrow shows a hemorrhage lesion where blood has leaked from a new blood vessel.

Figure 1: Abnormalities belonging to diabetic retinopathy:

(a) Microaneurysm (small red lesion); (b) Hemorrhages (dark red lesion); (c) Hard exudates (yellow lesions); (d) Soft exudate (yellow/whitish lesion); (e) Neovascularization (new blood vessels).
2. METHODOLOGY:

2.1 Existing Method:

![Block diagram](image1)

2.1.1 Contrast adjustment

A digital image f(x, y) is a two-dimensional function where x and y are spatial coordinates and amplitude f of at any pair of coordinates is called intensity or gray level of image at that point. Digital image processing is a composition of a finite number of elements called picture elements, image elements, or pixels. Image enhancement is one of the challenging issues in low level image processing.

The spatial entropy based contrast enhancement of an input image without altering the shape of the histogram with respect to original histogram. The corresponding input and output images of contrast adjustment and histograms are as shown in below figure.

![Input and contrast adjustment output image](image2)

![Histograms of input and contrast adjustment enhanced output image](image3)

2.1.2 Morphological Operations

Morphological operations play a key role in digital image processing with special application in the field of machine vision and automatic object detection. The morphological operations include dilation, erosion, opening, closing and skeletonization etc.

a) Dilation

Dilation is a process that thickens objects in a binary image. The extent of this thickening is controlled by the Structuring Element (SE) which is represented by a matrix of 0s and 1s. Mathematically, dilation operation can be written in terms of set notation as below.

\[ A \oplus A_s = \{ z | (A_s) \cap A \neq \emptyset \} \]

b) Erosion

Erosion shrinks or thins the objects in a binary image by the use of structuring element. The mathematical representation of erosion is as shown below.

\[ A \ominus A_s = \{ z | (A_s) \cap A_c \neq \emptyset \} \]

c) Opening and Closing

In image processing, dilation and erosion are used most often and in various combinations. An image may be subjected to series of dilations and or erosions using the same or different SE. The combination of this two principles leads to morphological image opening and morphological image closing. Morphological opening can be described as an erosion operation followed by a dilation operation. Morphological opening of image X by Y is denoted by X O Y, which is erosion of X by Y followed by dilation of the result obtain by Y closing and opening.

\[ X \circ Y = (X \ominus Y) \oplus Y \]

\[ X \bullet Y = (X \oplus Y) \ominus Y \]

d) Skeletonization:

Skeletonization is another way to reduce binary image objects to a set of thin strokes that can display important information about the shape of the original objects. Skeletonization is similar to thinning, except that
it maintains more information about the internal structure of objects with it being 1 pixel thick.

2.1.3 Fuzzy C-Means Clustering Algorithm of Segmentation

The FCM is another simple algorithm of segmenting or classifying images into k different clusters based on feature, attribute or intensity value.

The classification is done by minimizing the sum of the squares of distances between data and the corresponding clustering centroid. Type of distance calculation compatible with K-means Algorithm includes Mahalanobis and Euclidean distance etc.

Algorithm for FCM Segmentation
Step 1: Input data and number of clusters
Step 2: Calculate cluster (group) centroids based on initial guess value
Step 3: Calculate distance of each pixel from Class centroid
Step 4: Group pixels into k clusters based on minimal distance from centroids
Step 5: Calculate new centroid for each cluster
Step 6: Classify into groups based on new centroid and distance
Step 7: Test if any of centroid changes its position.
Step 8: If there are changes repeat step 3-8, else step 9
Step 9: end

2.2 Proposed Method:

2.2.3 Gabor Features

Gabor filters are generally applied in various applications like texture based image analysis, feature extraction, pattern recognition and computer vision etc. Generally the Gabor filter is a multiplicative form of complex trigonometric function with a Gaussian envelope, as represented in Eq. (3.8). In this work, the real portion of 2D Gabor filter response is used for minor blood vessels extraction.

\[
g(x,y;\lambda,\theta,\sigma,y) = \exp\left(-\frac{x^2+y^2}{2\sigma^2}\right)\cos\left(2\pi\frac{x}{\lambda}\right)
\]

Where \(x' = x . \cos \theta + y . \sin \theta, y' = -x . \sin \theta + y . \cos \theta\) and \(g\) is 2-D Gabor kernel function.

3. Comparison Results:

3.1 Existing Method (1,1)

3.2 Proposed Method (1,1)

Similarly we take eight different effected eyes those people are suffered from DR and calculate Sensitivity, Specificity and false positive rate.

\[
\text{Sensitivity} = \frac{TP}{TP+FN}
\]

\[
\text{Specificity} = \frac{TN}{TN+FP}
\]
First, it should be investigated how the fundus images should be taken. In other words, it should be studied whether it is enough to use a green filter and take gray-scale images containing only the wavelength of green color or whether a wider range of wavelengths should be used. In this study, lesions were searched only in the green channel of RGB color fundus images, but also other color channels may give additional information about lesions.

The second proposal concerns image segmentation and classification. The segmentation technique presented in this thesis is not very dynamical, and thus there may appear segmentation errors in some images. It may be necessary to use an image segmentation technique that finds separate object classes from each image and performs the segmentation according to the class information.

The third proposal for improvement is that different classifiers (rule-based, statistical, artificial neural networks, etc.) should be compared and the most suitable selected.

The fourth proposal is to optimize the used methods to achieve an adequate screening speed. The optimization may also involve the implementation of the developed methods as a stand-alone program, as the current Matlab-based implementation is relatively slow.

Finally, the fifth proposal is to use the ground truth of several ophthalmologists instead of a single one. In this study, it was not investigated how much difference there is between diagnoses made by different human screeners, but the ground truth of only one ophthalmologist was used. Since also ophthalmologists may make classification mistakes, it would be worthwhile to use only lesion information that is accepted by several ophthalmologists. When the results of the developed machine vision methods are published, it may be reasonable to mention how much variance there is among humanscreeners in addition to variance between the computer-based system and a humanscreener.

REFERENCES

4. CONCLUSION

The goal of this paper was to develop algorithms for detecting different abnormal lesions related to diabetic retinopathy. The lesion types of interest were microaneurysms, hemorrhages, hard exudates, soft exudates, and neovascularization.

Equalization of uneven illumination was found to be the key issue for the success of the research. Thus, existing illumination equalization methods were compared and the best method was selected. Since abnormal lesions are best visible in the green channel of an RGB color fundus image, the illumination-equalized green channel was used in the abnormality detection process. The abnormality detection process consisted of image segmentation and candidate lesion classification. In addition to thresholding, two novel methods were used in the image segmentation: a circular filter-based method for detecting small lesions and a morphology-based method for hemorrhage detection. Segmented candidate lesions were classified into lesions and non-lesions by using a simple rule-based classifier.

The results proved that it is possible to use algorithms for assisting an ophthalmologist to segment fundus images into normal parts and lesions, and thus support the ophthalmologist in his or her decision making. The algorithms detect regions where the image quality is inadequate, and thus it is possible to show to the ophthalmologist what regions are left unprocessed.

5 FUTURE SCOPE:

There are several proposals for improvements if more resources are available for researching machine vision-based diabetic retinopathy analysis.

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