Blood Vessel Detection from Fundus Image for Diabetic Retinopathy Patients using SVM

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Abstract **Diabetic retinopathy, the most common diabetic eye disease, occurs when blood vessels in the retina change, which lead to blindness if it is not treated. Blood vessel detection from Retinal images is a vital and challenging task for even experienced ophthalmologists. In this project, we have proposed a computer approach for the detection of diabetic retinopathy stage using color fundus images. The features are extracted from the fundus images using the image processing techniques namely edge enhancement with Kirsch template, grayscale conversion, histogram equalization, morphological processing, object classification and then fed to the support vector machine (SVM) which automatically detect the blood vessels as normal or Abnormal. This study attains the sensitivity of 96.07%, which is superior to the various other well-known techniques.**

Keywords—Fundus image, Diabetic Retinopathy, Kirsch template, sensitivity, Support vector machine (SVM)

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I. INTRODUCTION

Diabetic retinopathy is damage to the retina (retinopathy), specifically blood vessels in the retina, caused by complications of diabetes mellitus. Diabetic retinopathy can eventually lead to blindness if left untreated. Approximately 80% of all patients who have had diabetes for at least ten years suffer from some degree of diabetic retinopathy. The retina is the light sensitive membrane that covers the back of the eye. If diagnosed and treated early blindness is usually preventable. Diabetic retinopathy generally starts without any noticeable change in vision. However an eye doctor can detect the signs. Blood vessel extraction from the fundus images poses an important step to solve various practical applications, diagnosis of the retinal vessels and registration of retinal images acquired at different times. Blood vessel detection plays an important role in automated radiological diagnosis tic process. There are several existing segmentation methods but all of them failed to extract. In this project edge enchancement technique and object classification is focusing to remove the objects from the fundus image. Retinal vasculature has received attention by specialists in different pathologies, where the detection and analysis of retinal vasculature may lead to early diagnosis and prevention of several diseases, such as hypertension, diabetes, arteriosclerosis, cardiovascular disease and stroke. One of the well-known and commonest diseases that need a computer-aided medical diagnosis is diabetic retinopathy (DR), which leads in most cases to partial or even complete loss of visual capability. The accurate diagnosis of this disease depends upon some features which have to be analysed in order to quantify the severity level of the disease. Retinal blood vessels are considered as one of the most important features for the detection of DR. As diabetic retinopathy is a progressive disease, regular screening of the human retina is essential for reducing the proliferative diabetic retinopathy and for preventing the subsequent loss of visual capability. The edge enhancement technique and object classification is mainly focused in this paper to remove the small objects from the fundus image. The remaining part of this paper is organized as follows. The blood vessel extraction technique based on the mathematical morphology is described in proposed methodology section.

2. ANATOMY OF HUMAN EYE

Eye is like a camera. The external object is seen like the camera takes the picture of any object. Light enters the eye through a small hole called the pupil and is focused on the retina, which is like a camera film. Eye also has a focusing lens, which focuses images from different distances on the retina. The colour ring of the eye, the iris, controls the amount of light entering the eye. It closes when light is bright and opens when light is dim.

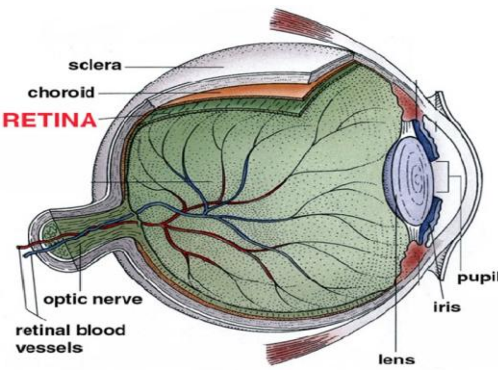

Fig. 1 Structure of eye

A tough white sheet called sclera covers the outside of the eye. Front of this sheet (sclera) is transparent in order to allow the light to enter the eye, the cornea. Ciliary muscles in ciliary body control the focusing of lens automatically. Choroid forms the vascular layer of the eye supplying nutrition to the eye structures. Image formed on the retina is transmitted to brain by optic nerve. The image is finally perceived by brain. A jelly like substance called vitreous humour fill the space between lens and retina. The lens, iris and cornea are nourished by clear fluid, aqueous humour, formed by the Ciliary body and fill the space between lens and cornea. This space is known as anterior chamber. The fluid flows from ciliary body to the pupil and is absorbed through the channels in the angle of anterior chamber. The delicate balance of aqueous production and absorption controls pressure within eye.

3. PROPOSED METHODOLOGY

The retina is a light-sensitive tissue lining the interior surface of the eye and is a layered structure with several layers of neurons interconnected by synapses. The vein and central retinal artery appear close by each other at the nasal side of the centre of the optic disk . Information about the structure of blood vessels can facilitate categorizing the severity of diseases and can also assist as a landmark during segmentation operation. the proposed method uses the following step: Edge enhancement, Grayscale conversion, Average filtering and histogram equalization, Binarization,Morphologicaloperation,Objectclassification, and Optical disk and border subtraction.

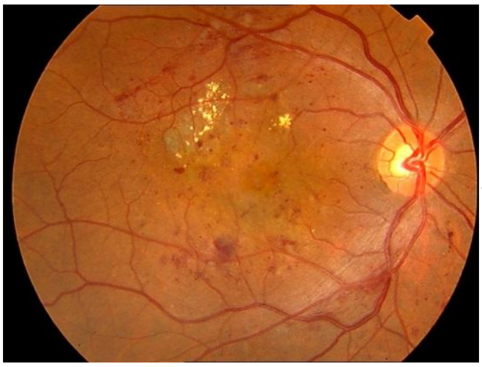

Fig. 2 Typical color fundus image

Fig. 2 shows an example of typical color fundus image is given as the input.Fig.3 shows the proposed methodology with the edge enchancement using Kirsch template, to extract the blood vessel and the images were feature extracted with subtracted images and imposed images whereas SVM is the classification technique used to train the images with the Radial basis function to test the trained image as normal or abnormal

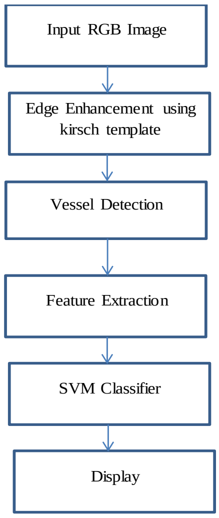

Fig. 3 Proposed methodology

3.1 EDGE ENHANCEMENT

Kirsch's template is used for detecting the blood vessels from the retinal images. Figure 4 shows the Kirsch's templates, which rotate automatically. The Kirsch's operator is one of the discrete versions of the first order derivatives used for edge enhancement and detection. For detecting the edges, the operator uses eight templates, which are consecutively rotated by 45°. The Kirsch operator or Kirsch compass kernel is a non-linear edge detector that finds the maximum edge strength in a few predetermined directions.

0°

5	-3	-3
5	0	-3
5	-3	-3

180°

-3	-3	5
-3	0	5
-3	-3	5

45°

-3	-3	-3
5	0	-3
5	5	-3

225°

-3	5	5
-3	0	5
-3	-3	-3

90°

-3	-3	-3
-3	0	-3
5	5	5

270°

5	5	5
-3	0	-3
-3	-3	-3

135°

-3	-3	-3
-3	0	5
-3	5	5

315°

5	5	-3
5	0	-3
-3	-3	-3

Fig.4 3x3 mask operators of kirsch templates

By convolving the image with eight template impulse response arrays in each and every pixel, the gradient is then computed

3.2 GRAYSCALE CONVERSION

In the grayscale conversion edge enhanced RGB is converted into grayscale image. To convert the RGB image to its grayscale form, it is needed to calculate the values of its red, green, and blue primaries in linear intensity encoding, by gamma expansion. If the output Gray image is I and the red, green, and blue components are R, G, and B, respectively, then

$$I = 0.33R + 0.5G + 0.166B$$

The intensity gradient between the foregrounds (blood vessels in this case) is relatively low with its background. To choose an accurate threshold value for segregating the objects of interest is a difficult task. Hence, edge enhancement or pre-processing of the image for subsequent analysis turns out to be essential. Therefore, an averaging filter of size 3x3 is chosen heuristically after several trials containing equal weights of "1", is applied to the grayscale image

3.3 IMAGE BINARIZATION

Image segmentation is a process of partitioning an image into regions such that each region is homogeneous and the union of two adjacent regions is not homogeneous. Thresholding based methods can be classified according to global or local thresholding and also as either bi-level thresholding or multi thresholding. The graylevel based on the statistical histogram ranges from 0 to L Between 0 and L, threshold K is chosen to segment the image into two classes: the background whose graylevel is from 0 to K and the target whose graylevel is from K+1 to L. If a certain threshold K can make the value of interclass variance σB the highest among all the possible values.

The threshold K is the one with which target and background can be accurately divided. The algorithm assumes that the image to be threshold contains two classes of pixels or bi-modal histogram e.g. foreground and background, then calculates the optimum threshold separating those two classes so that their intra-class variance is minimal. In the process of binarization, it is quite obvious that a high threshold value, close to 1 might provide an image containing all blood vessels.

3.4 MORPHOLOGICAL CLOSING

Morphological closing is necessary to close the holes or empty area within the blood vessel created through the Kirsch's template matching as demonstrated before. The closing of A by B is obtained by the dilation of A by B, followed by erosion of the resulting structure by B.

$$. \ A \bullet B = (A \oplus B) \theta B$$

3.5 REMOVAL OF SMALL OBJECTS USING OBJECT CLASSIFICATION

The blood vessel obtained from binarization process is not satisfactory because of noise and many small unwanted objects. At the first step of our procedure, we use Kirsch's method to enhance the edges, however, it also enhances the noise as well. As a result, the final binary output contains noise/unwanted small objects as well as some black vein going through the detected blood vessel. To eliminate or reduce these noises, we applied an operation based on calculating the area of each object in an image. This is a simple method to eliminate the unwanted species from the binary image. We first classified the whole image into different objects based on their area. The procedure is shown as follows. The area of the particular object contained by the image is to count the number of pixels in the object for which (j, k)=1. The perimeter of the enclosed object can be calculated by applying the following equation

$$A_E = \sum_{p=1}^{P_E} j\left(\left(p-1\right)\Delta k\left(p\right)\right)$$

where p_E is the perimeter. And,

$$j(P) = \sum_{i=1}^{p} \Delta j(i)$$

3.6 REMOVAL OF BORDER AND OPTIC DISK

To remove the border of the main task is to choose the appropriate marker and mask images. The original image f(x,y) is used as the mask image and the marker image fm is defined by the following equation

$$f_m(x,y) = \begin{cases} f(x,y) \text{ if } (x,y) \text{is on the border of } f \\ 0, \text{ otherwise} \end{cases}$$

To remove the optic disk in our study, detection of optic disk is implemented in the red channel of the fundus image in four steps: red channel extraction, grayscale conversion, histogram equalization, and binarization. Initially, the original RGB retinal image is taken. We observe that the optic disk is predominantly clearer in the red channel. Therefore, we choose the red channel only and convert it to grayscale. This shortcoming is astounded by linear histogram adjustment. Now, we use a simple technique to extract the region of the optic disk.

4. FEATURE EXTRACTION

In pattern recognition and in image processing, feature extraction is a special form of dimensionality reduction. When the input data to an algorithm is too large to be processed and it is suspected to be notoriously redundant (much data, but not much information) then the input data will be transformed into a reduced representation set of features (also named features vector). Transforming the input data into the set of features is called feature extraction. If the features extracted are carefully chosen it is expected that the features set will extract the relevant information from the input data in order to perform the desired task using this reduced representation instead of the full size input.

Feature extraction involves simplifying the amount of resources required to describe a large set of data accurately. Analysis with a large number of variables generally requires a large amount of memory and computation power or a classification algorithm which over fits the training sample and generalizes poorly to new samples. Feature extraction is a general term for methods of constructing combinations of the variables to get around these problems while still describing the data with sufficient accuracy. The input data should be transformed into a reduced representation of set of features such as Area Bounding box, Centroid, Eccentricity, Euler number and Diameter. To extract these features of the CT image, region properties are applied. These features are explained below.

- Area: The actual number of pixels in the region.
- Bounding Box: The smallest rectangle containing the region, a 1-by-Q *2 vector, where Q is the number of image dimensions.
- Centroid: 1-by-Q vector that specifies the center of mass of region.
- Eccentricity: Scalar that specifies the eccentricity of the ellipse that has the same second-moments as the region. The eccentricity is the ratio of the distance between the foci of the ellipse and its major axis length. The value is between 0 and 1. (0 and 1 are degenerate cases; an ellipse whose eccentricity is 0 is actually a circle, while an ellipse whose eccentricity is 1 is a line segment.) This property is supported only for 2-D input label matrices.
- Euler Number: Scalar that specifies the number of objects in region minus the number of holes in those objects. This property is supported only for 2-D input label matrices.
- Diameter: Scalar that specifies the diameter of a circle with the same area as the region. Computed as sqrt (4*Area/pi). This property is supported only for 2-D input label

5. SUPPORT VECTOR MACHINE

In the recent years, SVM classifiers have demonstrated excellent performance in a variety of pattern recognition problems. The input space is mapped into a high dimensional feature space. Then, the hyper plane that maximizes the margin of separation between classes is constructed. The points that lie closest to the decision surface are called *support vectors* directly affect its location. When the classes are non-separable, the optimal hyper plane is the one that minimizes the probability of classification error. General method of construction of the Optimal Hyper plane (HO) which separates from the data belonging to two different classes linearly separable is as follows

$$y_i\,(w.x_i + b) \geq 1 \quad i=1\dots m$$

SVMs are efficient learning approaches for training classifiers based on several functions like polynomial functions, radial basis functions, neural networks etc. It is considered as a supervised learning approach that produces input-output mapping functions from a labelled training dataset. SVM has significant learning ability and hence is broadly applied in pattern recognition. SVMs are universal approximates which depend on the statistical and optimizing theory. The SVM is particularly striking the biological analysis due to its capability to handle noise, large dataset and large input spaces.
The fundamental idea of SVM can be described as follows

a. Initially, the inputs are formulated as feature Vectors.
b. Then, by using the kernel function, these feature Vectors are mapped into a feature space.
c. Finally, a division is computed in the feature space to separate the classes of training vectors

A global hyper plane is sought by the SVM in order to separate both the classes of examples in training set and avoid over fitting. This phenomenon of SVM is more superior in comparison to other machine learning techniques which are based on artificial intelligence. The mapping of the input-output functions from a set of labelled training data set is generated by the supervised learning method called SVM. In a high dimensional feature space, SVM uses a hypothesis space of linear functions which are trained with a learning technique from optimization theory that employs a learning bias derived from statistical learning theory. In Support Vector machines, the classifier is created using a hyper-linear separating plane. It provides the ideal solution for problems which are not linearly separated in the input space. The original input space is non-linearly transformed into a high dimensional feature space, where an optimal separating hyper plane is found and the problem is solved. A maximal margin classifier with respect to the training data is obtained when the separating planes are optimal.

For binary classification SVM determines an Optimal Separating Hyper plane (OSH) which produces a maximum margin between two categories of data. To create an OSH, SVM maps data into a higher dimensional feature space and carries out this nonlinear mapping with the help of a kernel function. Then, SVM builds a linear OSH between two classes of data in the higher feature space. Data vectors that are closer to the OSH in the higher feature space are known as Support Vectors (SVs) and include all data necessary for classification.
A kernel function and the parameters should be selected for constructing the support vector machine classifier. Here, three kernel functions are used to construct SVM classifiers:

a. Linear kernel function
b. Polynomial kernel function
c. Radial basis function

The most used kernel function for SVM is Radial Basis Function (RBF) because of their localized and finite responses across the entire range of real x-axis. The classification accuracy of RBF kernel was high also, the bias value and the error rate of RBF kernel were small when compared to other kernels.

6. RADIAL BASIS FUNCTION

In machine learning, the (Gaussian) radial basis function kernel, or RBF kernel, is a popular kernel function used in support vector machine classification. The belief is that a classification problem cast into a higher dimensional space become more likely separable than in low dimensional space.RBF Network can be used to find a set weight for a curve fitting problem. The weights are in higher dimensional space than original data. Learning is equivalent to finding a surface in high dimensional space that provides the best fit to training data. Hidden layers provide a set of functions that constitute a arbitrary basis for input patterns when they are expanded to the hidden space these functions are called RBF

7. SCREENING OF DIABETIC RETINOPATHY

At the moment the screening of diabetic retinopathy is performed by trained medical experts. Sensitivity means the percentage of abnormal fundus classified as abnormal by the procedure.

Where TP, TN, FP and FN mean true positives, true negatives, false positives, and false negatives, respectively. A screened fundus is considered as a true positive if the fundus is really abnormal and if the screening procedure also classified it as abnormal. Similarly, a true negative means that the fundus is really normal and the procedure also classified it as normal. A false positive means that the fundus is really normal, but the procedure classified it as abnormal. A false negative means that the procedure classified the screened fundus as normal, but it really is abnormal.

8. RESULT AND DISCUSSION

The proposed blood vessel detection using edge enhancement and object classification with Support Vector Machine (SVM) was simulated using MATLAB. Typical color fundus image is given as the input. Edge enhancement using Kirsch template is used for sharpening of image features such as edges, boundaries or contrast. Grayscale conversion is used to choose an accurate threshold value and for detecting edges. Binarization is used to achieve the graylevel thresholding with the change in variation to show 1 as white and 0 as black.
Morphological closing is necessary to close the holes or empty area within the blood vessel .Object classification is used to eliminate or reduce the noises and unwanted spices from the binary image .One of the drawbacks of kirsch filter is that, it thickens the blood vessel more than it appears, so morphological erosion is used to extract the clear blood vessel.
After vessel detection by applying region properties different features are extracted. The features extracted are Area, Centroid, bounding box, convex area, convex hull, convex image, Eccentricity, Euler number, Extrema, Filled area, Filled image, Image, Perimeter are extracted.SVM is trained to detect whether the fundus image is Abnormal as shown in fig(5) or Normal as shown in fig(6).

The proposed method has been verified by taking 100 patients images to detect the blood vessel. In this approach, we proposed a method to automatically extract the blood vessels from fundus images. The color fundus images are enhanced using Morphological operation. Features based on shape, contrast, brightness are calculated and classified as normal or abnormal blood vessels using Support Vector Machine (SVM) Classifier. The proposed method performs best by segmenting even smaller blood vessels. All the work is done using MATLAB. Performance is verified by evaluating True Positive (TP, a number of abnormal pixels correctly detected), False Positive (FP, a number of normal pixels which are detected wrongly as abnormal pixels), False Negative (FN, number of abnormal pixels that are not detected), True Negative (TN, a number of normal pixels which are correctly identified as normal pixels).

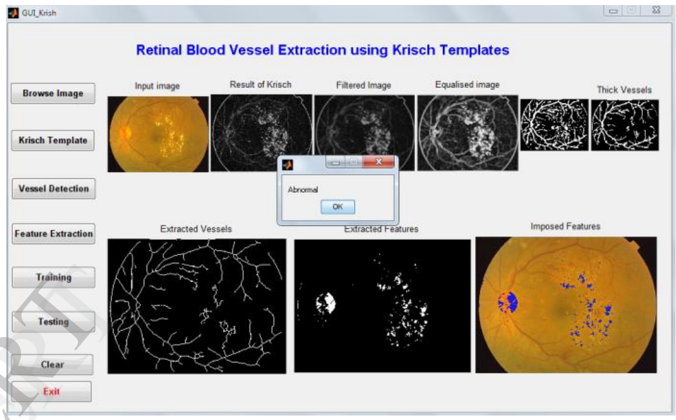

Fig. 5 Abnormal image

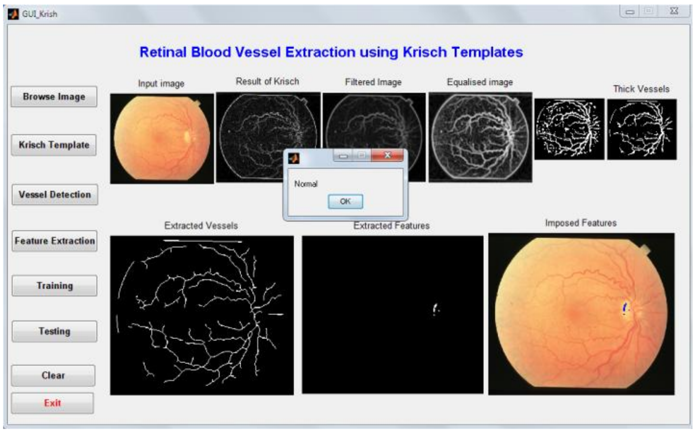

Fig. 6 Normal image

9. CONCLUSION

In this work, blood vessel detection technique based on edge enchancement and object classification was analyzed. The image processing of color fundus images has a significant role in the early diagnosis of Diabetic Retinopathy. In this paper, a novel method is presented for the detection of abnormal new blood vessels from the color fundus images. Finally the images are classified as normal and abnormal by the use of Support

Vector Machine (SVM) Classifier .It is clearly noticeable that the proposed technique significantly outperforms other well-known methods and the segmented image obtained using the proposed method is almost close (sensitivity of about 96.07 %).The vessel detection of segmented vessels can be applied in a clinical setting of computer assisted diagnosis however this work is used to detect the blood vessel in early stage for diabetic retinopathy patients It should be pointed out that the proposed technique will not replace the physicians or ophthalmologists. The results demonstrated here indicate that the system can help the ophthalmologist to detect diabetes retinopathy at the early stage.

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