Analysis of Retinal Vasculature by Watershed Segmentation and Histogram Analysis

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Abstract— *Retinal image analysis is becoming eminent as a nonintrusive diagnosis method in modern ophthalmology. This paper is mainly focused on the early diagnosis of diabetic retinopathy by analysing and detecting of vascular structures in retinal images. When small vessels in the retina have high level of glucose, it produces blur vision which eventually leads to blindness. Usually retinal images are taken from DRIVE dataset. The small vessels which are abnormal are not visible by naked eye are segmented accurately by watershed segmentation. Through watershed segmentation we enhance the blood vessel and suppress the background information. The segmented abnormal nerve image is compared with the healthy and normal nerve image through histogram equalization. Experimental results achieved from the proposed method effectively used to reduce the time for the ophthalmologist to detect disease and give accurate treatment.*

Keywords — *Retina, watershed segmentation, histogram*

I. INTRODUCTION

Diabetic retinopathy is the ocular manifestation which appears at retina due to diabetes. The diabetic retinopathy is common in 80% of people who has diabetes over 20 years or more. The diabetes mellitus is the impotence of the body to store and use the sugar properly emerging resulting in high blood-sugar levels [1]. Even though this disease has adverse effect on many parts of the body, it firstly affects the retina (patient's sight). The blood vessels in eye bring oxygen and nourish the retina. Due to diabetes, the blood vessels get damaged that leads to increase of insulin in blood, which obviously distort eye sight and even cause blindness. Research indicates that at least 90% of these diseases can be reduced and cured by early diagnosis, treatment and monitoring of retinal nerves.

Segmentation algorithms such as mathematical morphology, threshold examining, supervised classification, deformable models have been performed on retinal blood vessels [2]. The characteristics such as width, diameter, curvature etc. of retinal vessels from retinal image are analysed using improved matching filter which was proposed by M. Al-Rawi et al [3]. Zhu et al have presented the need for different detection and analysis methods on a wide range of retinal vessels present in fundus image [4].

Detection of the retinal blood vessel from fundus image can be done by watershed segmentation. Watershed of a greyscale image is similar to a catchment basin of a height map i.e. a drop of water following the gradient of an image flows along a path to finally reach the local minimum. Watershed lines are defined on nodes, edges, or hybrid lines on both nodes and edges and even in continuous domain [5].

Through histogram, the distribution of numerical data is represented. It estimates the quantitative variable present in the image. Here we adapt histogram based data interpretation, which is the most powerful tool for visualizing and analysing data. A histogram shows how data are distributed (grouped). Here the histogram indicates the intensity of the image. An image histogram is a chart that shows the distribution of intensities in an in a greyscale image. Histogram plot is obtained by defining *n* equally spaced bins, each representing a range of data values, and then calculating the number of pixels within each range. We can use the information in a histogram to choose an appropriate enhancement operation.

II. METHODOLOGY

Watershed transformation also termed, as watershed method is a dominant mathematical morphological tool for the segmentation of image [6]. The watershed algorithm for the continuous case can be rooted on distance function. Based on distance function we concentrate on one given in [7, 9], but other choices have been proposed as well [8].

For the sake of clearness, we will concentrate only on digital images. A grey-tone image can be represented by a function f: $z^2 \rightarrow z$. f(x) is the grey value of the image at a point x. The points of the space z^2 may be the vertices of a square or of a hexagonal grid.

A section of f at level I is a set X_i (f) defined as:

$$Xi(f) = \{x\epsilon z2 : f(x) \geq i\} \qquad (1)$$

In the similar way, we may define the set Z_i (f):

$$Zi(f) = \{x\epsilon z2 : f(x) \leq i\} \qquad (2)$$

We have obviously:

$$Xi(f) = Zi + 1(f) \qquad (3)$$

A. Morphological gradient:

The *morphological gradient* of a picture is explained as:

$$g(f) = (f + B) - (f - B) \qquad (4)$$

where (f + B) and (f – B) are respectively the elementary dilation and erosion of f[1].

When f is continuously differentiable, this gradient is equivalent to the modulus of the gradient of f:

$$g(f) = [\left(\frac{df}{dx}\right)\left(\frac{df}{dx}\right) + \left(\frac{df}{dy}\right)\left(\frac{df}{dy}\right)]\ 1/2 \qquad (5)$$

The fundamental way to approximate this modulus is to allocate to watch point x the difference between the highest and the lowest pixels within a given neighbourhood of x. In other words, for a function f, it is the difference between the dilated function (f + B) and eroded function (f – B).

B. Distance function:

Let Y be a set of z^2. For every point y of Y, define the distance of y to the complementary set Y^c:

$$y \epsilon DY, d(y) = dist(y, Yc\ ) \qquad (6)$$

It can easily be shown that a section of d at level I is given by:

$$Xi(d) = \{y : d(y) \geq i\} = Y - Bi \qquad (7)$$

where B_i is a disk of radius i.

C. Watershed transformation:

Assume an image f as an element of the space C(D) of real twice continuously differentiable function on a connected domain D with only isolated critical points. Then the topographical distance between points p and q in D is given by

$$\mathcal{T}f(p,q) = inf \int_{\gamma} ||\Delta f(\gamma(s))||\ ds \qquad (8)$$

Where the infimum is over all paths (smooth curves) γ inside D with $\gamma(0) = p$, $\gamma(1) = q$. The topographical distance between a point p ϵ D and a set A ϵ D is defined as $\mathcal{T}f(p, A) = MINa\epsilon A\ \mathcal{T}f(p, a)$.

The path with shortest T_f – distance between p and q is a path of steepest slope. This motivates the following rigorous definition of the watershed transform.

Watershed transform: Let f ϵ C(D) have minima $\{m_k\}_{k \epsilon I}$, for some index set I. the *catchment basin CB* (m_i) of a minimum m_i is defined as the set of points x ϵ D which are topographically closer to m_i than to any regional minimum m_j:

$$CB(mi) = \{x\epsilon D \mid j\epsilon I\{i\} : f(mi) + \mathcal{T}f(x, mi) < f(mj) + \mathcal{T}f(x, mj)\} \qquad (9)$$

The watershed of f is the set of points which do not belong to any catchment basin:

$$Wshed(f) = D \cap (\cup i\epsilon I CB(mi))c \qquad (10)$$

The *watershed transform* of f is a mapping $\lambda: D \rightarrow IU\ \{W\}$, such that

$$\lambda(p) = Iifp\epsilon CB\ (mi) \qquad (11)$$

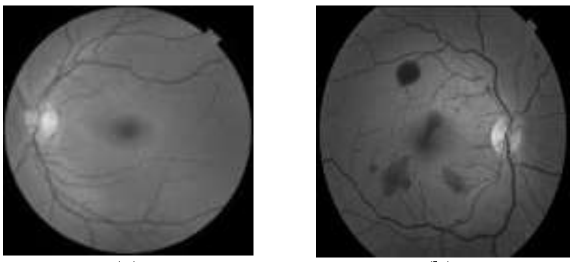
and $\lambda(p) = W$ if p ϵWshed(f)'

So the watershed transform of f assigns labels to the points of D, such that (i) different catchment basins are uniquely labelled, and (ii) a special label W is assigned to all points of the watershed of f.

III.RESULTS AND DISCUSSION

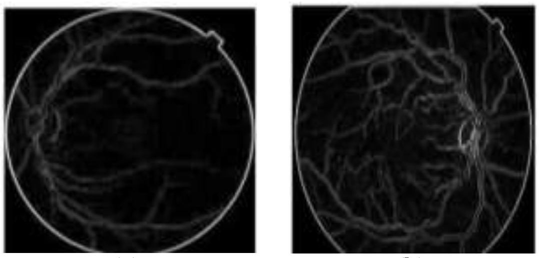
The input retinal images taken for the analysis is shown in Fig 1(a-b), where Fig 1(a) is a normal retinal image and Fig 1(b) is the abnormal retinal image. The images are subjected to watershed segmentation and the outputs are shown in Fig 2(a-b).

The results show the delineated pattern of the retinal vascular structure. The segmented outputs are compared with the inputs with the help of histogram equalization. The table 1 shows the histogram outputs for the input and output retinal images. Histogram based data analysis is an influential tool used for visualizing data. It is a chart which shows the distribution of intensities in an image. The advantage of histogram is that the background and the grey value range can be spotted at a glance.



(a) (b)

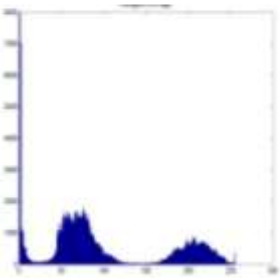
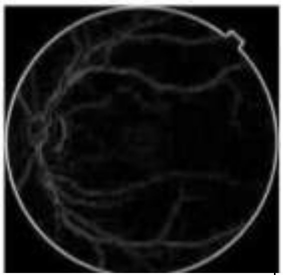
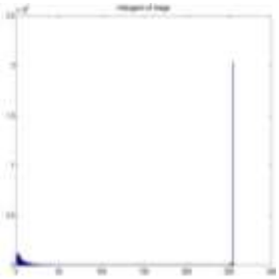
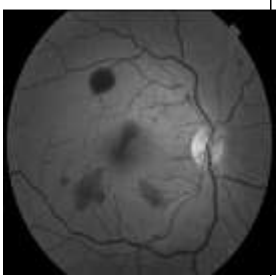
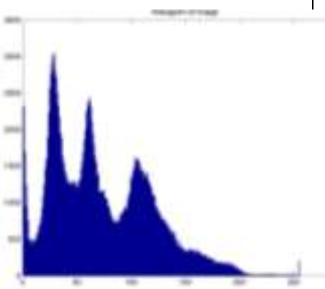
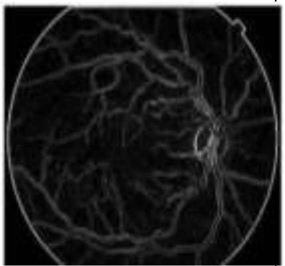
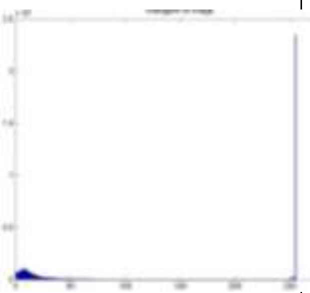
Fig 1(a-b). Representative input images



(a) (b)

Fig 2(a-b). Segmented output images

TABLE I. HISTOGRAM OUTPUTS

Original Image	Histogram before segmentation	Segmented Image	Histogram after segmentation
			
			

IV. Conclusions

Watershed based segmentation along with histogram equalization has been attempted in this paper. By using watershed segmentation, the vessels in the retinal images are identified. Further the histogram analysis gives the comparison of the inputs and outputs according to the intensity distribution. Thus this method can be used in the early diagnosis of diabetic retinopathy and further improvements to reduce the over segmentation are under study.

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