Retinal Vessel Detection in Retinopathy of Prematurity Using Butterworth High-pass Filters and SVM

Niousha Hormozi, Seyed Amirhassan Monadjemi, Gholamali Naderian

Abstract*— Retinopathy of prematurity (ROP) is an eye disease in premature infants. It mostly happens in babies weighing less than 0011 g and gestational age less than 10 weeks. The growth of retinal vessels are interrupted in premature infants and the retina has been unable to get enough oxygen and food. So, the delay in diagnosis may lead to blindness. Therefore it is necessary to follow the premature infants in regular checkups to assure that their vessel structure is growing normal. In this paper a high pass filter is used to track the retinal vessels and the energy criterion is computed for finding the percentage of area which is covered with blood vessels. The algorithm has been applied on 011 images including both mature and premature infants. The pictures are taken with a Retcam and labeled by an ophthalmologist. The result of this study was compared with ophthalmologist's hand labels of diagnosis and it can detect the prematurity with a high specificity of 0111, sensitivity of %29.61 and accuracy of %59101 .

Index Terms*—Butterworth high-pass filter, ROP, SVM.

I. INTRODUCTION

ROP is a disorder that cause blindness in children [1]. In infants who are born earlier than normal (premature infants), before the vessels can completely mask the retina vessels environment, growth stops. It happens in some premature infants which their retinal vascular growth has not been complete after birth [2]. The ophthalmologist could obtain useful information from the examination of retinal blood vessels for ROP diagnosis [0]. So, the vascular structure is so important and using image processing tools could be efficient for extracting that structure and could make the diagnosis and automatic computerized. Structural changes in the vessel can be studied in several ways: direct examination by ophthalmoscope, and by examining photographs of the retina. Ophthalmoscope is a device that helps to see retinas in a large angle. The problem is only a qualified physician can do the job. There has been limited work for analyzing ROP images automatically so far. Until now, mostly retinal photographs or film slides were photographed so it was hard to do automatic machine based diagnosis [4].

II. VESSEL EXTRACTION ISSUES

There are some problems in describing the vessel model in an image, since it depends on many factors like texture characteristics and light source.

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So getting an accurate model of vessels is not easy. Some factors that affect blood vessel segmentation are:
- Vessels are not of the same, shape and color. Vein width varies from one pixel to 12 pixels in some images.
- Different structures exist in retinal image such as border of retina, or nerves, that are similar to vessels.
- Points of intersection and divergence of the vascular may distract the techniques.
- The edge of disk may be classified as vessels incorrectly.
- Sometimes there is low contrast between background and the foreground. Thin veins usually have lower contrast with the background [5],[0].

Generally there are two types of vessel detectors, edge detectors and matched filters. In edge detection (e.g. Sobel operator, morphological operator, gradient operator, etc), right and left edges of the vessel are identified using an edge detector [5].

III. VESSEL EXTRACTION TECHNIQUES

Here are some techniques used in the vascular diagnosis:

1- Morphology

Vessels have piecewise–linear property making them suitable for morphology. Morphology performs well in vasodilatation extraction. It has good speed and is robust against noise as well [2],[8].

2- Neural networks

Neural networks could be trained to recognize patterns like vessels and extract the vessel structure in retinal images. Neural network classification is based on the statistical probabilities. You must have an overview of the phenomena and principles to use neural networks in image processing. That has got some advantages and disadvantages as well. For example neural networks must have been trained, in this case with some images labeled by an expert ophthalmologist which is a disadvantage [4].

0- Match filter

Using match filters in tracing vessels helps in small Retinal Vessel Detection in Retinopathy of Prematurity Using Butterworth High-pass Filters and SVM bifurcate vessels ignorance. In other words only the main branch is followed [2]. The filter output would be maximum when the filter rotation and the orientation of the vessel Niousha Hormozi, Seyed Amirhassan Monadjemi, Gholamali Naderian Retinal Vessel Detection in Retinopathy of Prematurity Using Butterworth High-pass Filters and SVM coincides. As a result the vessel's location and orientation is determined.

Filter window size is adjusted to fit the width of the vessel, in other words a standard filter is linearly becoming big or small, to match the vessel. This helps to create a filter that is large enough to cover wide vessels and also small enough to avoid finding additional patterns. A large filter may give wrong answers to many of patterns, because usually there are lesions around capillaries and thin vessels are usually tortuous [5]. This filter works on vessels as piecewise – linear. The advantage of template-based algorithms is that parallel computation is performed on each pixel. As the size of convolution mask increases we get better performance (less sensitivity to noise), but the computational cost increases significantly. Overlay, the results of the algorithms are optimum, and they are less sensitive to noise, but their main disadvantage is the computational cost, since the convolution of an image is conducted with different directions of a segment [2].

4- Sobel operator

Using a standard sobel operator, local intensity gradient is calculated. The respond to non-ideal step edges is not suitable [2].

5- Laplacian operator:

It is used to reduce the effect of high frequency noise. We could convolve the original image with a two-dimensional Gaussian window to reduce the bandwidth before applying the Laplacian filter. But convolution has too much cost, as mentioned above.

0- Second order Gaussian filter

It is shown in [5] that Gaussian curves are useful for modeling the vessels. Figure 1 show this based on an estimation process. Consistency of "vessel estimation diagram" with a Gaussian function is evaluated and a second order Gaussian filter with scaling domain is suggested for the detection and measurement of vessels. Disadvantages are that it responds to many non-vessel structures, and is less sensitive to small vessels [0].

Figure 0- estimation of vessel diagram with Gaussian model

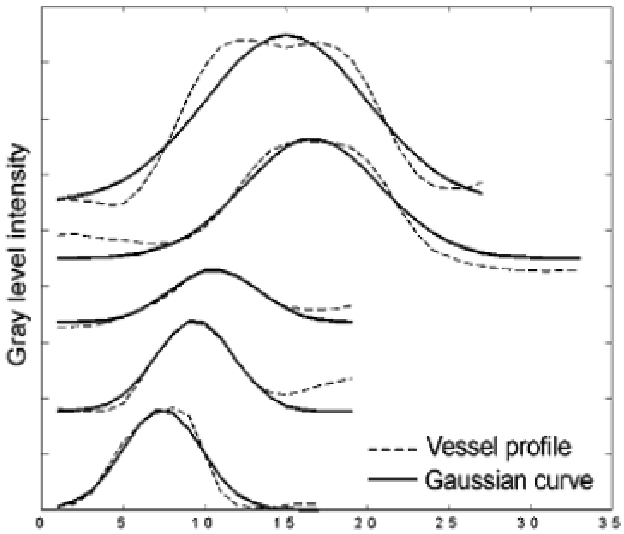

Figure ١- estimation of vessel diagram with Gaussian model

Some other approaches:

In [13] fuzzy clustering algorithm is used for tracking vessels in retinal angiogram images. In [11] vessel extraction from two-dimensional images using the technique of the scale space with sub-voxel accuracy is used. In [12] neural networks are used to detect the edge intensity, and after applying PCA on the input image, a multi-layer perceptron is used to diagnose blood vessels. In [10] the continuous Wavelet transform and morphological operators are applied to segment the retinal vessels. Linear structural morphology elements is employed to promote the blood vessel, usually only large vessels are well recognized, and further steps to remove responses that are non-vascular structures are required. In [14] retinal vessel detection is done by Laplacian and thresholding. A threshold method usually works well when the contrast between background and vascular structure is high [0].

These methods mostly have good performance when they are applied on adult images, but they work unsuccessfully on infant images. Blood vessel structure of infants and adults are different in several parameters such as resolution, image noise, and thickness. It is very difficult to detect vessels in infant images yet but both are equally important issues [15].

In Figure 2 and 0 structural differences between infant and adult eyes are shown.

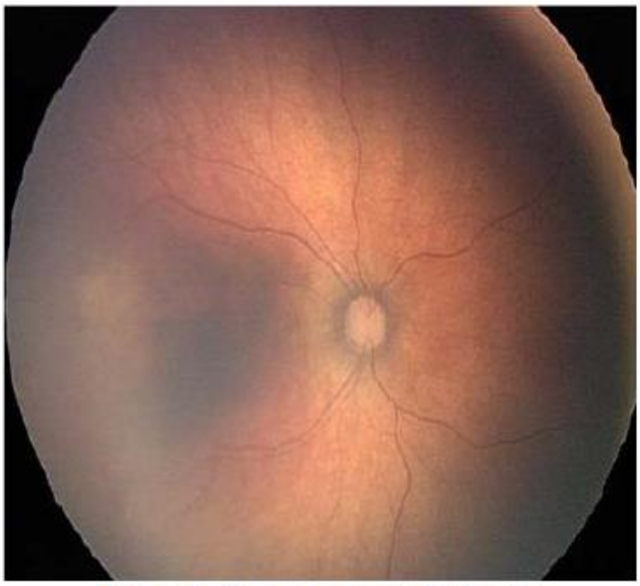

Figure ٢- An example of infant retina

Figure 6- An example of infant retina

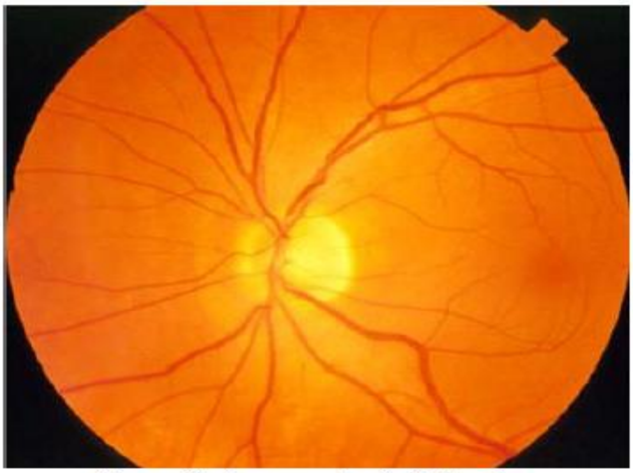

Figure ٣- An example of adult retina

Figure 1- An example of adult retina 0

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IV. PREVIOUS WORKS ON INFANT EYES

Here are some works that have been done on infant eye images, processing towards clinical applications.

In [4] a combination of morphology and linear filters is applied for segmentation of vascular structures. The quality depends on selected threshold and structural elements.

In [15] after comparing the performance of applying edge detector on a set of photographs of newborns, LOG (Laplacian of Gaussian) was chosen. Then Otsou threshold was used for thresholding the filtered images.

There is a lot of good work have been conducted on adult retinal images in the field of image processing techniques, but most of these techniques fails on baby's imperfect retinal image.

In [10] edge detection techniques in automatic results in classification were compared to infants retinal vessels. The results are compared with the images that are manually line drawn, to assess the accuracy of the method. These edge detection methods are applied in two categories, gradient-based edge detection and zero crossing edge detection.

In [12] CAIAR (Computer Aided Image Analysis of Retina) is used for semi-automatic detection and measurement of retinal vessel diameter and vessel tortuosity of digital images, accuracy of this algorithm is assessed by generating vessel-like lines with known frequency, amplitude and width, by computer. The locus of the center of the vessel is grouped together by wrapping continuous frame structures, to measure the tortuosity. Each vessel is skeletonized as a skeletal structure of one pixel thickness. ML estimation method and LOG filter is used to estimate the diameter of the vessel.

V. METHODS

Filters modify the appearance of digital images for processing. Filter is a system that passes some frequencies and other frequencies are weaken or eliminated. Filter Band-pass is the range of frequencies that can pass through the filter with little attenuation. The critical frequency is also called the cutoff frequency, usually defined as the frequency at which the response is half of the maximum response in the band pass. High pass filters, pass frequencies above a certain value, and do not let the lower frequencies to pass. High-pass filters have many applications for edge detection in gray level digital medical images and are effective in removing low frequency information. They are used to sharpen the edge pixels and other details. A useful feature of object recognition is shape and edge information, Therefore the edges have many applications in machine vision and discrimination. Edges are defined as boundary between an object and the background, or the boundary between overlapping objects.

In this paper we applied Butterworth high pass filter to detect vessels in infant retinas.

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We employed 133 labeled images to classify mature and premature babies. Butterworth high pass filter is applied to detect vessels and the extraction occurs with a proper threshold in binary image. We chose energy feature to evaluate the amount of edges that exist in an image. This could represent the information in an image which is the amount of grown vessels in the infant's eye here. It is demonstrated that energy is an efficient criterion that could be a representation of existence edges and shows the completed vessels, in this paper. We also used sensitivity criterion to measure how much our method does well.

VI. RESULTS

This proposed method is applied on 133 premature infants in two groups of premature and mature images. In this method, a second-order Butterworth high-pass filter with a cutoff frequency of 43 is used, and then we got a binary image with a threshold of 5. Finally, we calculated the energy of image and gave it to SVM with a linear kernel function, for classification. It concluded sensitivity result %29.67, specificity result %007, and accuracy %59087 and mean square error 096.

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