Iraqi Journal of Physics, 2020 *Vol.18, No.44, PP. 1-16*
DOI: 10.20723/ijp.18.44.1-16

Blood vessels detection of diabetic retinopathy from retinal fundus image using morphological operations

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Abstract

Early detection of eye diseases can forestall visual deficiency and vision loss. There are several types of human eye diseases, for example, diabetic retinopathy, glaucoma, arteriosclerosis, and hypertension. Diabetic retinopathy (DR) which is brought about by diabetes causes the retinal vessels harmed and blood leakage in the retina. Retinal blood vessels have a huge job in the detection and treatment of different retinal diseases. Thus, retinal vasculature extraction is significant to help experts for the finding and treatment of systematic diseases. Accordingly, early detection and consequent treatment are fundamental for influenced patients to protect their vision. The aim of this reseaech is to utilized image processing techniques to detect blood vessels from the digital fundus images.

This research will present a methodology to separate retinal blood vessel network. The suggested system in this research involves four stages, after image acquisition, the pre-processes of the image to preparing and improving the image quality is the first stage. Morphological operations are used for the detection of blood vessels. In this research, we use two morphological operations: erosion and dilation. These two tasks have two sources of info, a binary image, and a structuring element object. We utilize two morphological procedures ((boundary extraction and Top, Bottom Hat transform). Before these operations, we will use applying a canny edge detector technique to obtain the edges of the retina image. The technique is tried on shading retinal images acquired from STARE and DRIVE databases which are accessible on the web as well as the samples of retinal images were obtained from the digital camera from Ibn Al-Haytham specialist Hospital for Eye in Baghdad, Iraq. The results obtained from these techniques showed the efficiency of these methods in the detection of blood vessels, especially when using morphological methods after the detection of edges.

Key words
Diabetic retinopathy, blood vessels, canny edge detections, morphological operations.

Article info.
Received: Jul. 2019
Accepted: Oct. 2019
Published: Mar. 2020

الكشف عن الاوعية الدموية لاعتلال الشبكية السكري من صورة قاع العين باستخدام العمليات التشكيلية

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الخلاصة
الكشف المبكر لأمراض العين يمكن أن يمنع القصور البصري وفقدان النظر. هناك عدة أنواع من أمراض العين البشرية، على سبيل المثال، اعتلال الشبكية السكري، وداء الزرقة، وتصلب الشرايين وارتفاع ضغط الدم. اعتلال الشبكية السكري الناتج عن داء السكري يسبب تلف الأوعية الدموية وتسرب الدم في شبكية العين. الأوعية الدموية في شبكية العين لديها مهمة كبيرة في الكشف عن أمراض الشبكية المختلفة وعلاجها. وبالتالي، فإن استخلاص هذه الأوعية الدموية مهم لمساعدة الاطباء في اكتشاف وعلاج الأمراض التي تخص العين. وفقا لذلك، يعد الاكتشاف المبكر والعلاج السريع أساسيين للمرضى لحمايتهم من فقدان النظر. الهدف من هذا البحث هو استخدام تقنيات معالجة الصور لغرض اكتشاف الاوعية الدموية من صور قاع العين الرقمية.
في هذا البحث، تم تقديم طريقة لفصل شبكة الأوعية الدموية في شبكية العين. يتضمن النظام المقترح في هذا البحث أربع مراحل، بعد الحصول على الصور، فإن العمليات الأولية للصورة لإعداد وتحسين جودة الصورة هي المرحلة الأولى. تستخدم العمليات المورفولوجية للكشف عن الأوعية الدموية. تم استخدام عمليتين مورفولوجيتين: التآكل والتمدد. هاتين العمليتين لها مدخلان، صورة ثنائية، وكائن عنصر هيكلي. سنستخدم عمليتين تشكليتين (boundary extraction and Top, Bottom Hat Transform). قبل هذه العمليات، سوف نستخدم تطبيق تقنية كاشف الحافة للحصول على حواف صورة شبكية العين. تم اختبار هذه التقنية على تظليل الصور الشبكية المكتسبة من قواعد بيانات STARE و DRIVE التي يمكن الوصول إليها في شبكة الإنترنت، كما تم الحصول على عينات من صور شبكية العين من الكاميرا الرقمية في مستشفى ابن الهيثم التخصصي للعيون في بغداد، العراق. تم الحصول على نتائج جيدة وفعالة للأوعية الدموية التي تم اكتشافها واستخراجها.

Introduction

Diabetes has related troubles, for instance, vision misfortune, heart disillusionment, and stroke. Patients with diabetes are bound to create eye issues, for example, waterfalls and glaucoma; however the illness' impact on the retina is the principle risk to vision. Intricacy of diabetes, causing variations from the norm in the retina and in the most pessimistic scenario serious vision misfortune, is called diabetic retinopathy. Diabetes is a notable malady and may cause variations from the norm in the retina. This sort of retinal variation from the norm is known as diabetic retinopathy [1]. For example, diabetic retinopathy which is brought about by diabetes causes the retinal vessels harmed and blood spillage in the retina. It is a prominent place among the most broadly perceived contaminations that reason visual lack. One out of three diabetic individual presents seems to have of diabetic retinopathy and one out of ten experiences its most extreme and vision-compromising structures. Diabetic retinopathy is grouped into two phases. These stages are proliferative diabetic retinopathy (PDR) and non-proliferative diabetic retinopathy (NPDR). Early location and ensuing treatment is fundamental for influenced patients to save their vision. In diabetes, fundus imaging assumes a significant job for observing the retinal variations from the norm, for example, diabetic retinopathy. DR can be dealt with utilizing accessible medications, which are successful whenever analyzed early. Since diabetic retinopathy is asymptomatic until late in the ailment procedure, ordinary eye fundus examination is important to screen any adjustments in the retina, [2].

Different viewpoints and phases of retinopathy are broke down by inspecting the hued retinal images. Microaneurysms are little common pockets brought about by neighborhood distension of fine dividers and show up as small red points. Their dividers are slim and burst effectively to cause hemorrhages. Hard exudates are yellow lipid stores which show up as splendid yellow sores [3]. Retinal vasculature extraction has a couple of troubles, for instance, pathological diseases and noises observed in the retinal fundus images. Additionally, it is seen that retinal images have low contrast between veins and the retinal background [4]. Assessment of blood vessels (BV) in the human eye allows for prior recognition of eye infections, such as, glaucoma and diabetic retinopathy. Computerized image preparing procedures to assume an imperative job in retinal blood vessels discovery, image processing techniques and channels to distinguish and separate the traits of retinal Blood Vessel [5]. The morphological operation consists of two sorts; essential operations and derivative. essential operations are, dilation, erosion and (hit & miss), though the derivative operations are: open, close, top Hat, base Hat, skeleton. The way toward finding the limits of the image (edge detection) the boundary between the neighboring regions which vary from one another in d gray levels value [6].

Problem definition

This research will present a methodology to separate retinal blood vessel by design a computer-aided blood vessels (BV) detection system of diabetic retinopathy from retinal fundus images of the human eye that detects disease at an early stage. The execution depends on canny edge detection and morphological task. In this research, we will use two morphological operations: erosion and dilation (boundary extraction and top, bottom hat transform).

Diabetes and diabetic retinopathy

Diabetes mellitus (DM) is the name of a chronic, systemic, life-threatening disease It happens when the pancreas cannot discharge enough insulin or the body can't process it appropriately. This results in an abnormal increase in the glucose level in the blood. Over time this high level of glucose causes damage to blood vessels. That harm influences the two eyes and nervous system, just as heart, kidneys and different organs [7].

In general, there are two sorts of diabetes. Diabetes type 1 results from a mistake of the human body to convey insulin. Type-1 diabetes is less ordinary than sort 2 diabetes [2]. Over time, diabetes affects the circulatory system, including that of the retina .It is a notable malady and may cause variations from the norm in the retina. This sort of retinal variation from the norm is known as diabetic retinopathy (DR). For example, diabetic retinopathy which is brought about by diabetes causes the retinal vessels harmed and blood spillage in the retina. Diabetic retinopathy (DR) is where the retina is harmed on the grounds that liquid breaks from blood vessels into the retina. Since the microvascular structures in the retina are powerless against high glucose levels, they are seriously harmed. The pericyte cells which support the vessel walls die and vessel walls become fragile and permeable [8].

Diabetic retinopathy (DR) is one of the most well-known confusions of diabetes and is one of the main sources of visual deficiency. In the retina, it can be characterized by blockage and damage of small blood vessels. A person who has diabetes for longer time then it is more likely that the person is suffering from this disease. If this disease not handle properly than it can interfere with patient’s vision [3].

There are two stages of diabetic retinopathy. The primary stage is called non-proliferative DR and the secondary or advanced stage is known as proliferative PDR. During the non-proliferative (NPDR) stage, the retinal blood vessels cannot withstand the high concentration of glucose and other sugars such as fructose in the blood, and get damaged. It significantly damages the mural cells which form an interior lining of vessels, the basement membrane and endothelial cell lining, all of which help forming a blood in the retina barrier and prevent blood leakage. Due to the deterioration of mural cells and endothelial lining, blood vessel walls become fragile and ultimately break down or leak. Leakage from blood vessels may lead to various pathological conditions like blood hemorrhages [9].

Abnormalities in the vascular pattern of a retina, for example, morphologic changes in vessel shape, branching pattern, width, tortuosity, or the presence of retinal lesions, might be related with the event of retinopathies or cardiovascular maladies. Accordingly, computerized quantitative investigation of changes in vessel morphology may show the clinical indications of the previously mentioned retinopathies, portraying their initial event or seriousness. The reactions got from various kinds of retinal vessels, i.e., supply routes and veins might be variable to retinopathies and their estimation may prompt a progressively exact analysis contrasted with that by the normal reaction represented the whole vessel arrange. Fig.1 shows various conditions resulting from non-proliferative diabetic retinopathy [10].

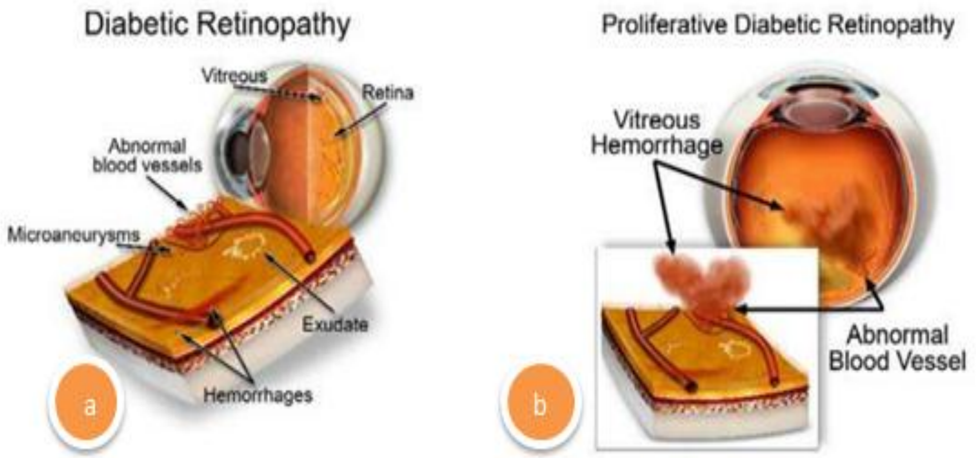


Fig.1: Abnormal retinal images illustrate the artifacts of diabetic retinopathy a) Non-proliferative, b) Proliferative [10].

Edge detection

Edge detection of an article is a significant apparatus in numerous Personal computers PC vision applications and it is utilized to discover the limits of the various items in a image. It is one of the most critical pieces of picture taking care of, picture examination, and verifiable model affirmation. The importance of the edges is in their viewpoint wherein they give an ideal point of view of the article in the picture. With the utilization of the article edges, it is conceivable to acquire adequate information on picture investigation. The achievement in the item acknowledgment stage relies upon the precision of the edge detection [11].

There is a variety of edge detectors which we encourage the student to learn and practice most of the classic edge detection operators such: Canny, Zero-crossing, LOG, Roberts, Roberts, Prewitt, Sobel, are the examples of Gradient-based edge detection methods [12, 13].

Canny detection

The Canny edge detection algorithm is a multi-arrange edge detection algorithm intended to identify sharp edges in the image. Created by John F. Vigilant in 1986. Albeit more complex than other edge detection algorithm, Canny is a standout amongst other edge detection algorithms. With a Canny edge detection algorithm, it creates edges with a solitary pixel thickness and consolidations broken lines [14].

Morphological operations

The mean word of morphology implies the investigation of structure or structure. In image processing, we utilize scientific morphology as a way to distinguish and separate significant image descriptors dependent on properties of structure or shape within the image. Key regions of utilization are segmentation together with automated counting and assessment. Morphology incorporates an incredible and significant assemblage of strategies which can be decisively treated numerically within the framework of set theory. While this set-theoretic system offers the points of interest related with scientific meticulousness, it isn't promptly open to the less scientifically prepared peruse and the focal thoughts and employments of morphology can be substantially more easily grasped through a pragmatic and natural exchange. Morphological operations can be connected to pictures of numerous types, but the primary use for morphology is for processing binary images and the key morphological operators are the moderately straightforward ones called dilation and erosion. It is, in fact, possible to show that many more sophisticated morphological procedures can be diminished to a succession of dilations and erosions [15].

Dilation and erosion

The two most important morphological operators are dilation and erosion. All other morphological operations can be defined in terms of these primitive operators. We denote a general image by *A* and an arbitrary structuring element by *B* and speak of the erosion/dilation of *A* by *B*. The mechanics of dilation and erosion operate in a very similar way to the convolution kernels employed in spatial filtering. The structuring element slides over the image so that its center pixel successively lies on top of each foreground or background pixel as appropriate. The new value of each image pixel then depends on the values of the pixels in the neighborhood defined by the structuring element. Fig.2 shows the results of dilation and erosion on a simple binary image. The foreground pixels are shaded and the background pixels are clear. In the diagram demonstrating dilation, the newly created foreground pixels are shaded darker to differentiate them from the original foreground pixels. Note that whenever the structuring element goes over the boundary of the image, we only consider that part of the neighborhood that lies within the boundary of the image [16].

A closing operation is performed on intensity component *I* image using two different sizes of a structuring element (filter). Closing operation is defined as dilation (Max filter) followed by erosion (Min filter). The formulations of dilation and erosion for gray scale images are as follows.

Dilation:

$$A \oplus B = A_1(x, y) = \sup_{i,j \in b} (A(x-i, y-j) + B(i, j)). \quad (1)$$

Erosion:

$$A \ominus B = A_2(x, y) = \inf_{i,j \in b_1} (A(x-i, y-j) + B1(i, j)). \quad (2)$$

where; *A* is the input image, *B* and B_1 are the structuring elements or masks used for dilation and erosion respectively. *b* and b_1 are grids over which the structuring elements are defined. In this research we will to use two morphological operations boundary extraction and top, bottom hat transform.

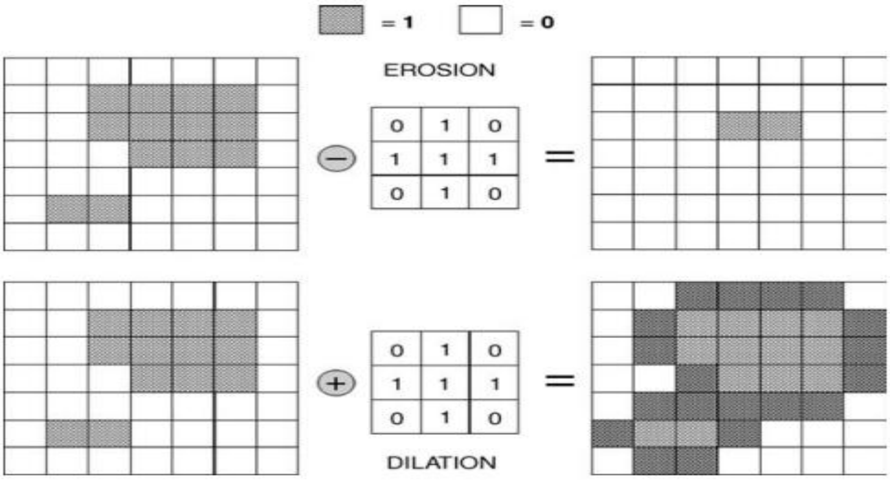


Fig.2: The erosion and dilation of a simple binary image [16].

i. Boundary extraction

We can characterize the boundary of an object by first dissolving the item with a reasonable small structuring element and after that subtracting the result from the original image. In this manner, for a binary image *A* and structuring element *B*, the boundary A_P is characterized as:

$$A_p=A-A\ominus B \quad (3)$$

ii. Top hat transform

The Top-Hat method is characterized as the difference between the original image and its opening. The opening of an image is the collection of closer view portions of an image that fit a specific structuring element.

$$A \bullet B = A -(A\ominus B)\oplus B \quad (4)$$

iii. Bottom hat transform

The Bottom-Hat method is characterized as the distinction between the closing of the original image and the original image. The closing of a image is the addition of background parts of an image that fit a specific structuring element.

$$A.B= ((A\oplus B) \ominus B))- A \quad (5)$$

where *A* is the original image, *B* is the structure element, symbol (•) is the combination of dilation operation and erosion, symbol⊕ denotes dilation and symbol ⊖ denoted erosion operation.

Methodology

In this section, the proposed method can be described to detect the features of diabetic retinopathy This is done by applying algorithms to detect retinal blood vessels. The suggested system for blood vessel detection involves four stages, firstly acquisition of a sample retinal fundus images database and examination of these images for the application. Second stage is the pre-processes of an image to improve quality and reduce artifacts. Morphological operations are used for the detection of blood vessels. Two morphological operations were applied: erosion and dilation. These two tasks have two sources of info, a binary image, and a structuring element object. Then, two morphological procedures ((boundary extraction and Top, Bottom Hat transform). Before these operations, we will use applying a canny edge detector technique to obtain the edges of the retina image. The overall retinal image analysis system stages are shown in

Fig.3 for blood vessel detection methods.

1. Acquisition retinal images

The initial step is to get a unique shading fundus images. In this work, various samples of retinal fundus images were utilized to appraise the adequacy of the proposed system. The technique is tried on shading retinal pictures acquired from STARE and DRIVE databases which are accessible on the web as well as the samples of retinal images were obtained from the computerized camera from Ibn Al-Haytham expert Hospital for Eye in Baghdad, Iraq. In dataset image, the resolution of obtained digital fundus color images has 1150 ×1234.

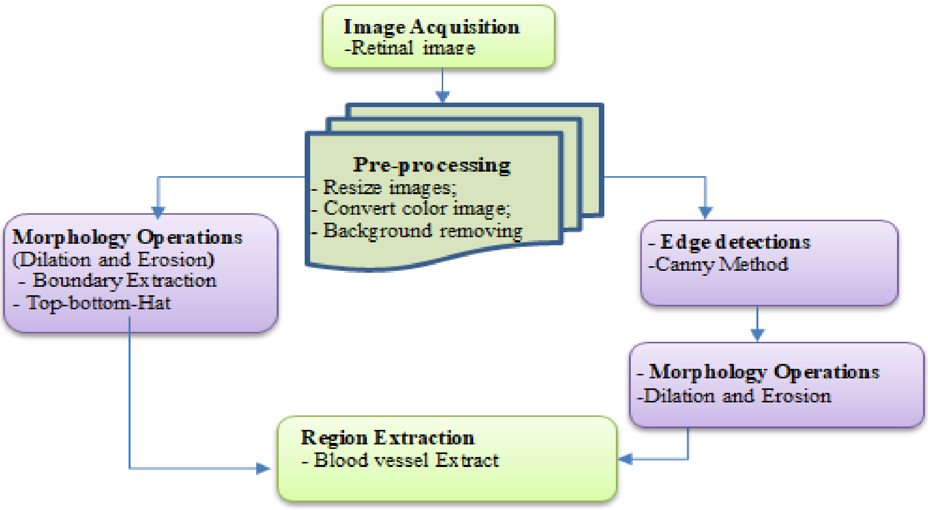


Fig. 3: Block diagram of the proposed system.

2. Pre-processing stage (PPS)

Pre-processing phase involves sub-phases such as resized, color space conversion, zero paddings of image edges and histogram equalization. In our present research, initially resized the acquired fundus images to a standard size of the spatial resolution of 570 ×550 pixels with 256 grey levels for each band. The acquired fundus images are some of the time of low quality. Regular issues with Fundus Images (FI's) include the presence of noise, low resolution, and uneven illumination. Pre-processing of the retinal image is one of the most important steps. The principle reason for pre-processing is to improve the contrast of the retinal image.

a. Conversion RGB to HSI

The input retinal fundus images can either be a RGB or grey [17]. The original color image is converted to hue, saturation, and intensity (HSI) color components. The intensity component I is the only one employed for further processing. The select of HSI depends on the fact that the intensity component of the image can be separated from other components. In this research, the information needed for the diagnosis can be obtained from the intensity space. The HSI stands for the Hue, Saturation and Intensity and RGB is which R stands for red, G represents the green and B is the blue. The hue and saturation components are intimately related to the way human eye perceives. The intensity represents of a color, which is decoupled from the color information in the represented image. The transformation equations for RGB to HSI color model conversion is given below [18].

$$I = \max(R, G, B) \quad (6)$$

$$S = \frac{I - \min(R, G, B)}{I} \quad (7)$$

$$H = \frac{G - B}{6S} \qquad , if\ I = R \quad (8)$$

The illumination of the retina is often irregular, resulting in local brightness and variance contrast. Leading to those lesions may be invisible in areas of low contrast and/or low brightness. Further, in the context of telemedicine, images are variable in terms of color and quality. Here we are going to work with gray-scale images because exudates are mostly visible in such images. As a result, pre-processing steps are required to address these problems. Fig.4 shows the color space conversion from RGB to HIS.

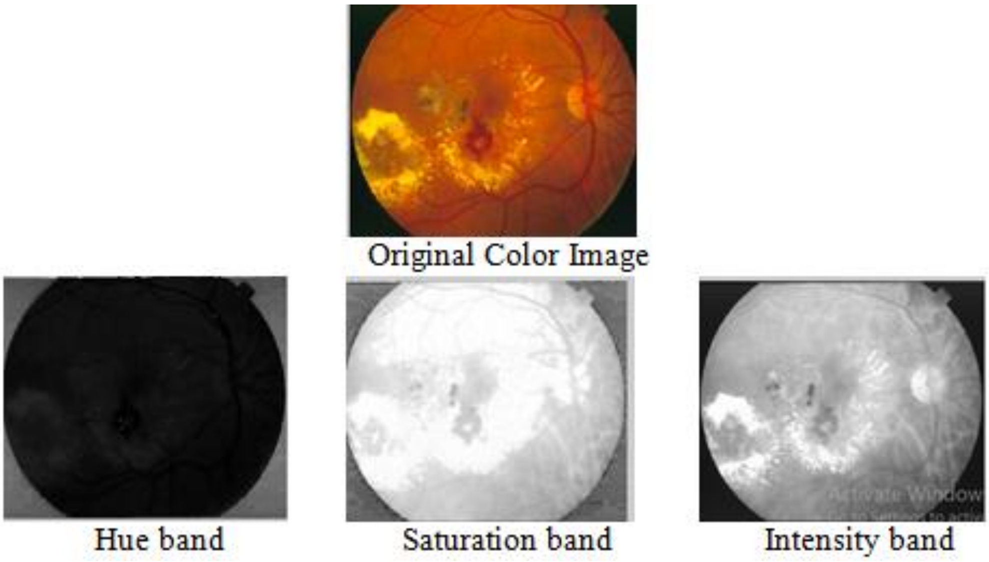
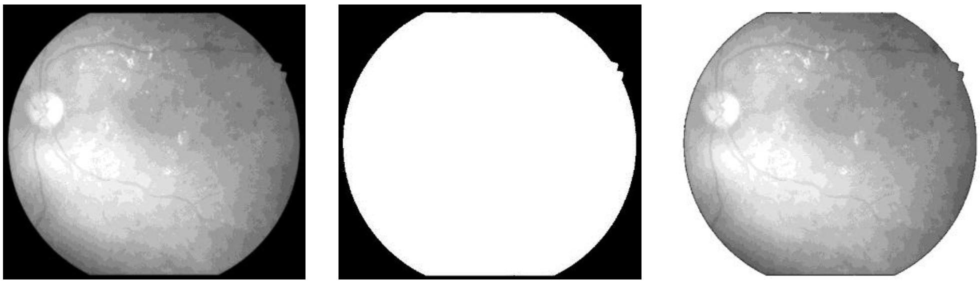


Fig.4: The color spaces convert process from RGB to HIS.

b. Background removing

Usually, in some Fundus Images FIs, retina information is contained in a circularly shaped region surrounded by an outer black region. The intensity of this black area is in the range of 0 to 32 (On a scale of 0-255), which much of the time can be considered as noise. The quality of the image can be affected by the presence of such noise. In order to remove the outer black region from the fundus images, it's important to create a mask which is a binary image (0 or 1's). This mask which has the size of the retinal fundus images and its value and shape differ from one image to another is applied on the original retinal images to discard the irrelevant information multiplying the mask image with study image it produced the masked image which is the extract retinal image. This mask is used to subtract the outer black region in the image [19]. Fig.5 shows a sample of the mask creation performed to crop outer black region. Fig.6 shows the histogram of images before and after crop outer black region.



Intensity component The Mask Extracted Image

Fig.5: The mask creation performed to crop outer black region.

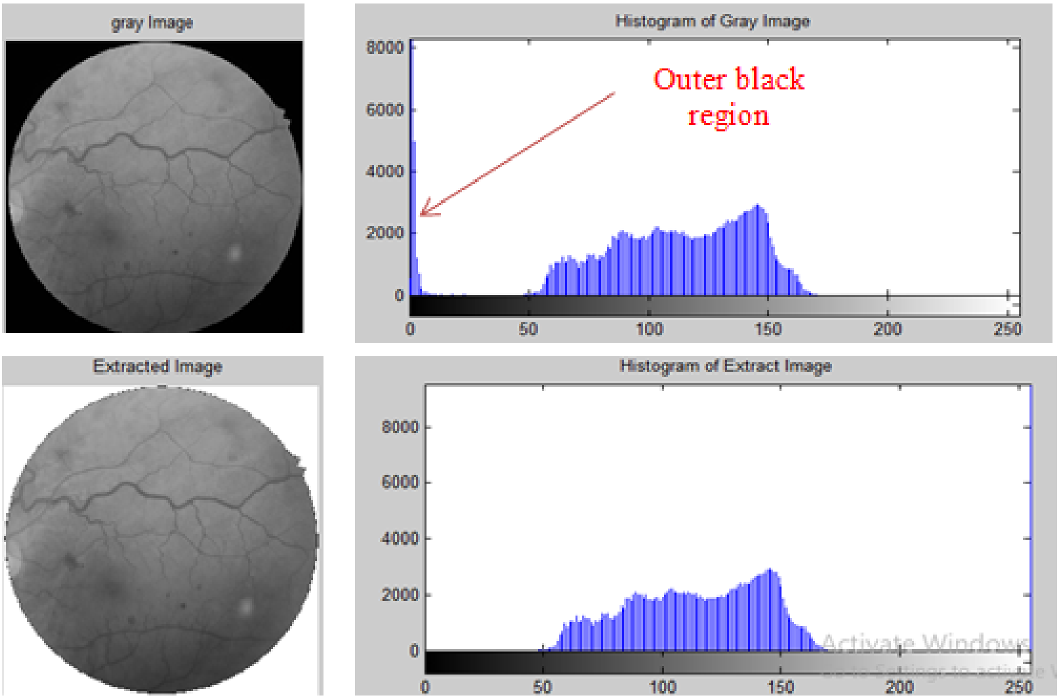


Fig.6: The images and their histograms before and after crop outer black region.

Results and discussion

a. Canny edge detection algorithm

First, in Fig.7, we will use the canny edge detector method to obtain the edges of the retina image. We will observe how changing the thresholds of the detector wills affect the edges of the output. We will use 6 different thresholds: 0.05, 0.1, 0.15, 0.2, 0.25, and 0.3. One should use the color space intensity (I) band input.

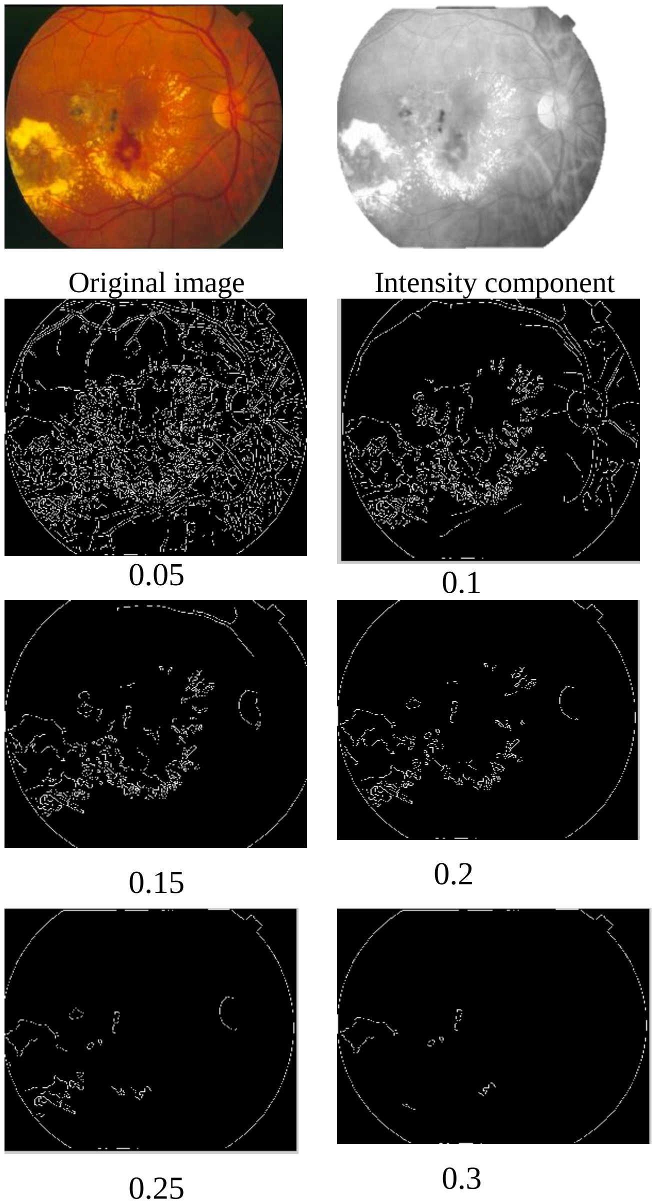


Fig.7: Canny edge detector to obtain the edges of the retina image using 6 different thresholds: 0.05, 0.1, 0.15, 0.2, 0.25, and 0.3 respectively.

b. Morphological processing methods

In this part we will utilize two morphological activities; limit extraction and Top, Bottom Hat. These two tasks have two information sources, a binary image, and a structuring element object. This structuring element can have different shapes, like a line, square, or disk and it represents the number of pixels that will be expanded or shrunk. By using boundary extraction we can define the boundary of an object by first eroding the object with a suitable small structuring element and then subtracting the result from the original image. Note that the thickness of the boundary can be controlled through the specific choice of the structuring element B in Eq.(1).

i. Boundary extraction method

Fig.8 demonstrates the results of the morphological operation using boundary extraction technique. The figure illustrates canny edge detector of the retina binary image, binary image after erosion and binary image after dilation with thresholds: 0.05, 0.1, 0.15, 0.2, 0.25, and 0.3 respectively. We can observe that, because the lines of the edges are too thin, applying erosion to the image makes the edges disappear. In contrast to erosion, dilation makes the edges thick.

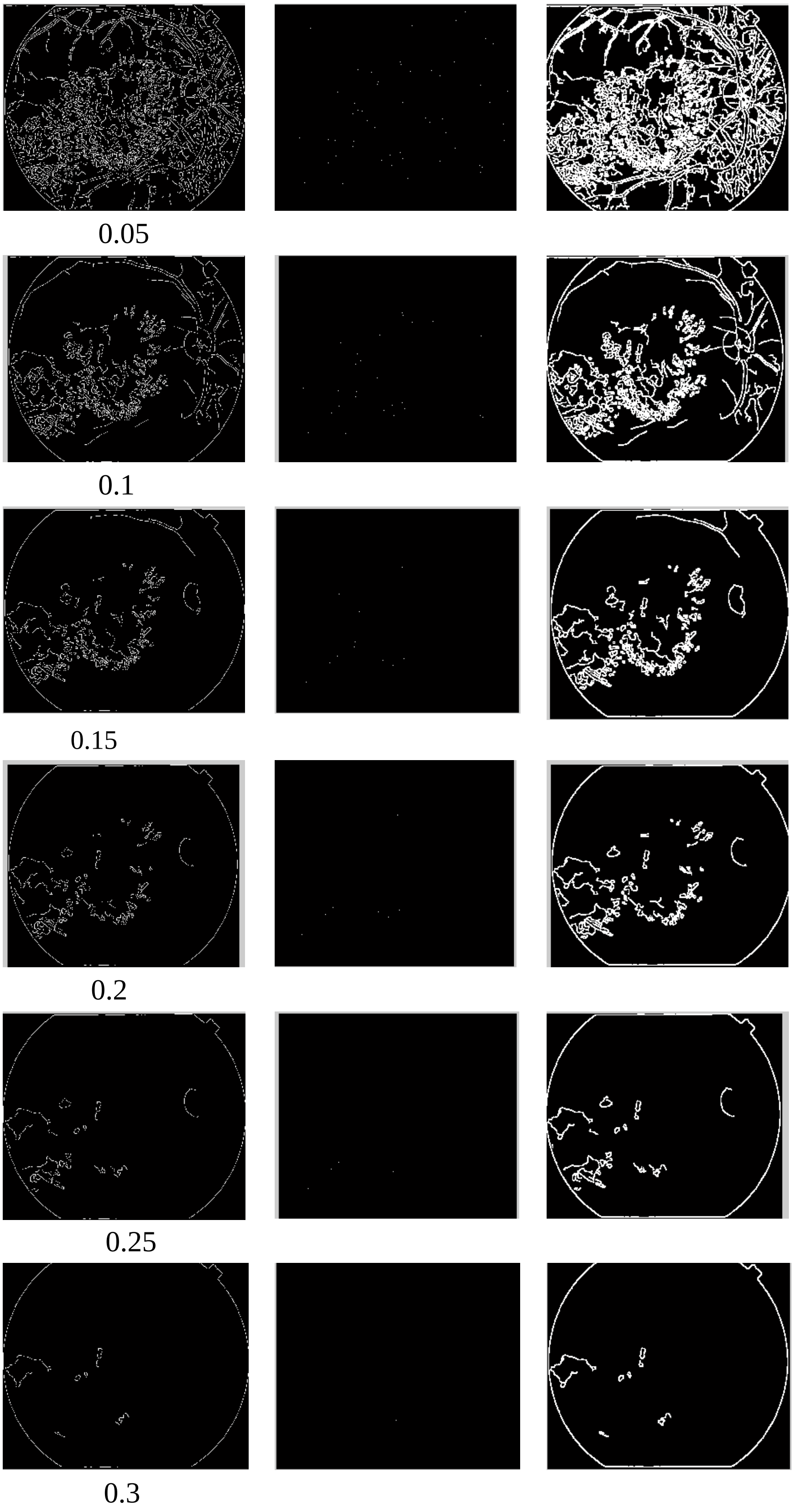


Fig.8: From left to right, canny edge detector binary image, binary image after erosion, and binary image after dilation with thresholds: 0.05, 0.1, 0.15, 0.2, 0.25, and 0.3 respectively.

ii. Top hat transform

The Top-Hat method is characterized as the difference between the original image and its opening. The implementation of the Top-Hat method can be done using the following algorithm:

The Top Hat algorithm

Step 1: Read the input image A of size M × N

Step 2: Initialize the structuring element B which is a square matrix with all zeros or ones

Step 3: Morphological opening is applied to the original image with the structuring element created in step 2

Opening Image: = A . B;

Step 4: The combination of dilation and erosion is

$A . B := (A \ominus B) \oplus B$,

Step 4: Apply Top Hat filter by subtracting the opening Image from the original image

Top Hat:= A– opening Image;

Step 5: Transformed image is displayed.

iii. Bottom hat transform

The Bottom-Hat method is characterized as the distinction between the closing of the original image and the original image. The closing of image is the addition of background parts of an image that fit a specific structuring element. The implementation of the bottom-hat method can be done using the following algorithm:

The Bottom-Hat Algorithm

Step 1: Read the input image A of size M × N

Step 2: Initialize the structuring element B which is a square matrix with all zeros or ones

Step 3: Morphological closing is applied to the original image with the structuring element created in step 2

ClosingImage: = A . B;

Step 4:the combination of dilation and erosion is

$A . B := (A \oplus B) \ominus B$,

Step 5: Apply bottom hat filter by subtracting the closing Image from the original image

Bottom Hat:= A– closingImage;

Step 6: Transformed image is displayed.

Figs.9, 10 and 11 shows the implementation of retinal fundus images do contain blood vessels (abnormalities) that can be detected using simple morphological operations using Top, Bottom Hat method for three different cases.

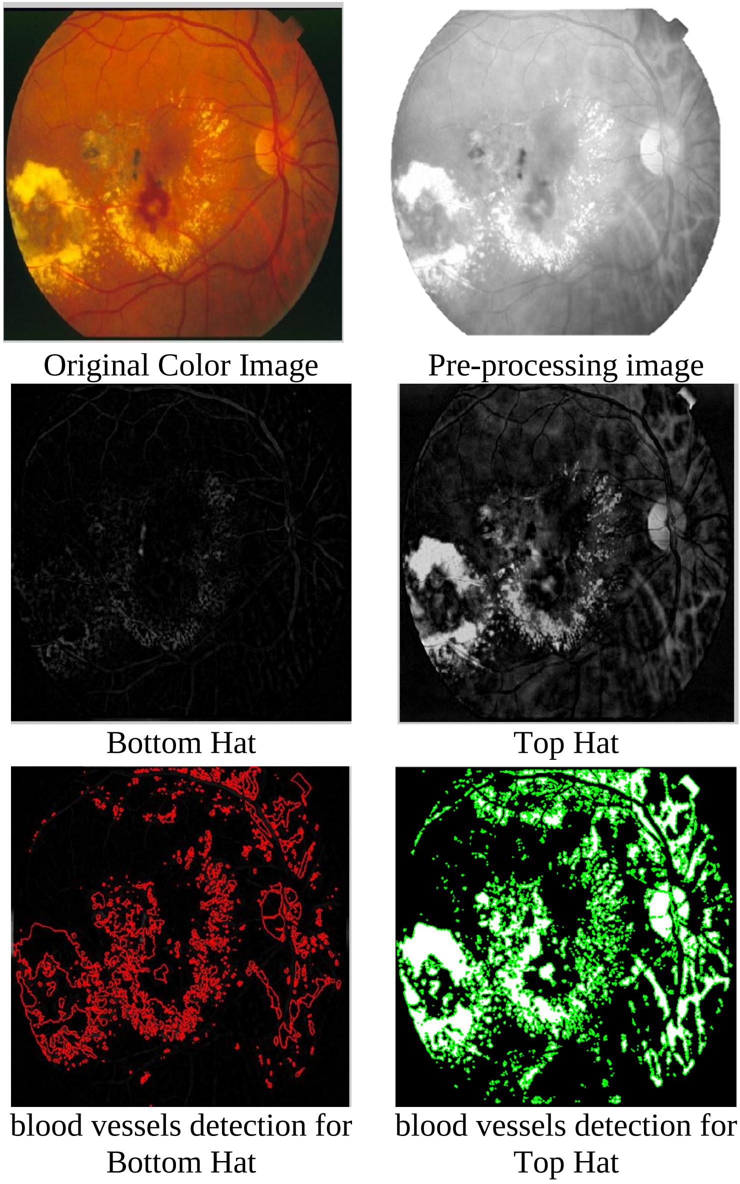


Fig.9: Retinal fundus images which contain blood vessels (abnormalities) that can be detected using simple morphological operations using top, bottom hat method.

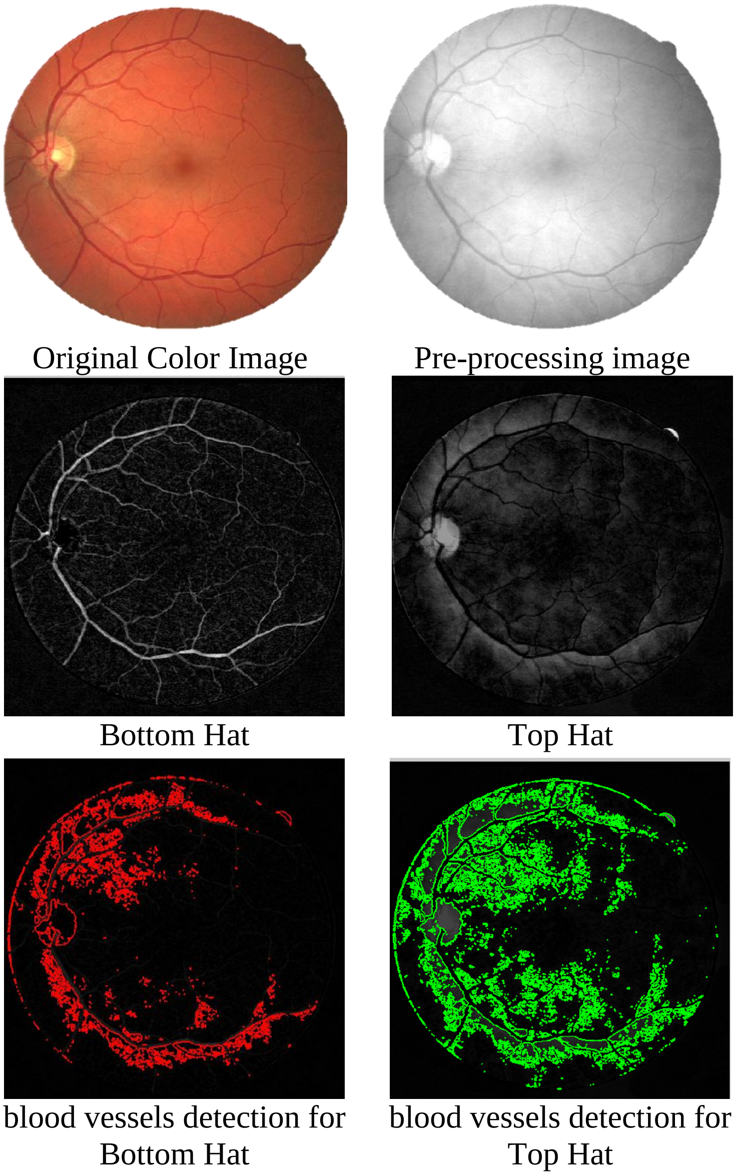


Fig.10: Retinal fundus images which contain blood vessels (abnormalities) that can be detected using simple morphological operations using top, bottom hat method (from left).

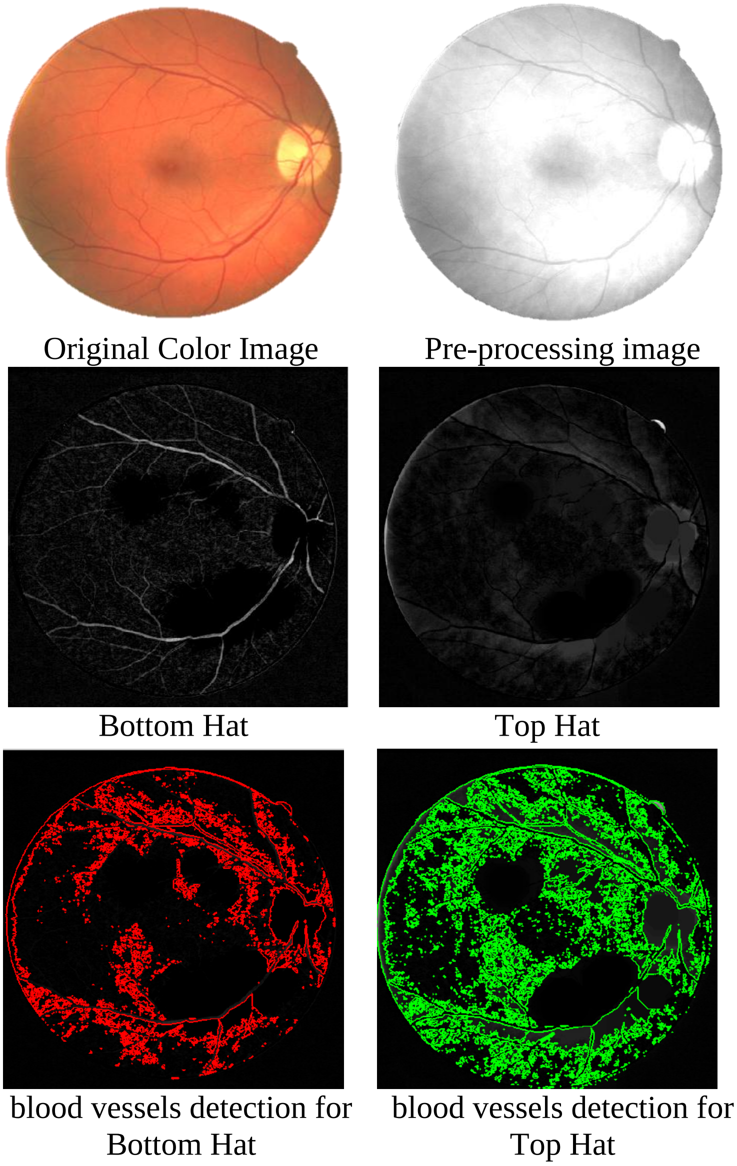


Fig. 11: Retinal fundus images which contain blood vessels (abnormalities) that can be detected using simple morphological operations using top, bottom hat method (from right).

Conclusions

In this paper, a fast and efficient method for extracting blood vessel in color eye fundus image has been presented. The computer aided automatic detection and segmentation system for retinal blood vessels has been proposed the contrast of the Fundus image tends to be bright in the center and diminish at the side, hence preprocessing is essential to minimize this effect and have a more uniform image. The Fundus image is initially resized to a standard size of 570 ×550. The intensity band (represents of a color) of Fundus image is used. Canny edge detection with morphology task has been applied. We have used two morphological operations; boundary extraction and Top, Bottom Hat) the experimental result shows high precision image. By using image processing technique we have achieved good result and effective for blood vessel detected and extract.

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