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An Automated Method for Detecting Exudates and Hemorrhages in the Retina's Images of Patients Suffering Diabetic Retinopathy

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Abstract

This paper presents an automated method for the detection of exudates and hemorrhages in retina images. The images used here were obtained by the clinical study called "fluorescein angiography" applied to patients who are suffering diabetic retinopathy. Diabetic retinopathy is a condition caused by diabetes prolonged exposition; the condition impairs the vision and could lead to lose it all. Exudates and hemorrhages are two of the damages presented in diabetic retinopathy. The exudates are rounded or oval yellowish-white coatings with indistinct borders and are located superficially in the retina's nerve fiber layer. On the other hand, hemorrhages occur when an abnormal bleeding is located inside the retina's blood vessels.

Keywords: Diabetic retinopathy, digital image processing, hemorrhages, exudates.

1 Introduction

All The extraction of different entities which shape an image is an image processing fundamental task. This process called segmentation often is obligatory in all the artificial vision systems, and depending on the task to solve, there are different methodologies which have been made to attack all these problems. Generally, image segmentation is the isolation process of the objects which shape an image, in other words, is an image division made in disjointed regions, every region is homogeneous about certain properties, such as gray levels, contrast, texture, etc [5], [8], [16].

Medical image segmentation helps as an important tool for evaluations and clinical diagnoses [4], [15]. The results are useful to doctors for the correct organs and tissues recognition, therefore the diagnostic efficiency rises and the image analysis workload decreases. However, medical image segmentation is particularly difficult because of the restrictions imposed by the image acquisition, pathologies and biological variables [3], [9], [11].

This paper presents a methodology applied on a medical image segmentation problem, specifically, it takes the segmentation of exudates and hemorrhages in retina images which was obtained through fluorescein angiography studies applied on patients who suffering diabetic retinopathy.

Diabetic retinopathy is a condition caused by diabetes prolonged exposition. The diabetic retinopathy is the process where the blood vessels begin to deteriorate because of the amount of glucose in the blood, the result, the blood vessels begin to break down cause the appearance of hemorrhages, also appear yellowish fatty substances which are deposited in the retina, these substances are called exudates [1], [7], [14].

2 Proposed Method

Before going into details of the proposed method it is necessary to mention the digital image definition. A digital image is a two-dimensional function $f(x, y)$ of the light intensity (brightness) at a point in space, where (x, y) are the point coordinates [12]. As a digital image is a function $f(x, y)$ discretized both spatial coordinates and in brightness, usually it is presented as a two-dimensional matrix $F_{ij} = (f_{ij})m \times n$ where m and n represent the image size and $f_{ij} = f(xi, xj)$.

Figure 1 shows a patient retina image who suffers diabetic retinopathy and where the exudates and hemorrhages can be appreciated.

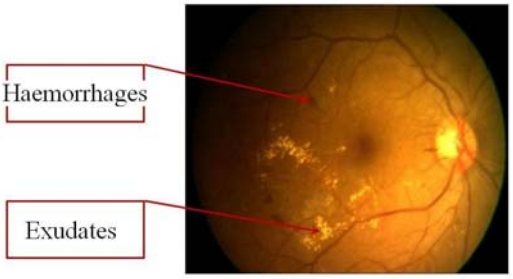

Figure 1: Presence of exudates and hemorrhages in the retinal vascular network of a patient who suffers diabetic retinopathy.

2.1 Obtaining the image in grayscale

An image in grayscale can be obtained extracting the green canal from breakdown of an color image in the three canals RGB. [6].

2.2 Laplacian of Gaussian filter

A The Laplacian of Gaussian filter allows to detect edges by smoothing the image with the application of the second derivative on the Gaussian filter equation [11]. The equation which is defined by the Laplacian when the mask used is the one showed in figure 2 is:

$$\bigtriangledown^2 f = 4_{z5} - (z_2 + z_4 + z_6 + z_8)$$

0	-1	0
-1	4	-1
0	-1	0

Figure 2: Mask to calculate the Laplacian.

2.3 Segmentation by Binarization with threshold a-b

Is the realization of a route in the image matrix representation and assign a binary value (0 is for black and 255 for white) to each pixel which is dependent of the thresholds a y b. If (x, y) represents the coordinates of an pixel and $f(x, y)$ the value which corresponding in grayscale, then the binarization by threshold $a - b$ is the following [6]:

$$f(x,y) = \begin{cases} 0 & \text{si } a \leq f(x,y) \leq b \\ 255 & \text{si } f(x,y) < a \text{ o } f(x,y) > b \end{cases}$$

2.4 Median Filter

The median filter replaces each image pixel for the pixels median in the mask which is containing the close neighbours [6]. For example if we considering the figure 3, in ascending order the pixels values covered by the mask are 115, 119, 120, 123, 124, 125, 126, 127 y 150 and the median value is 124.

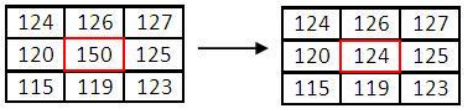

Figure 3: Mask to calculate the Laplacian.

The obtaining hemorrhages method consists of five steps:(1) The obtaining of the image in grayscale. (2) Segmentation by binarization with threshold a-b. (3) Dilatation. (4) Removal of objects and (5) Erosion.

The mathematical morphology is a mathematical tool based on set theory and is used with huge success in the binary images digital process [2]. The fundamental operations of mathematical morphology are the dilatation and the erosion. [13].

2.5 Dilatation

The dilatation is the process referred to increase, grow or expand a body through a controlled process of added or aggregation of points or elements. In order to establish the control of growth process is taken another conjunction with simple structure and shape as reference, it is called structuring element. In mathematical terms, if A is a binary image and B is a structuring element, then the dilatation of A by B, denoted as $A \oplus B$ is [10]:

$$A \oplus B = \{a + b \mid a \in A \text{ y } b \in B\}$$

2.6 Removal of objects

To remove large objects was considered the 8-connectivity, namely, a pixel p is connecting with a pixel q, if p belongs to the neighbourhood of its 8 neighbours of q [6] (figure 4). Once every pixel is connected, if these exceed the given threshold, all the connected pixels are removed.

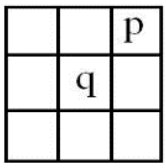

Figure 4: The pixel p is connected with pixel q through the 8-connectivity.

2.7 Erosion

The erosion consists of the decrease of a set A through a controlled elimination process of elements, with a structuring element B as reference. In mathematical terms, if A is a set and B an structuring element, then the erosion of A by B, denoted as $A \ominus B$ is [10]:

$$A \ominus B = \{x \mid x + b \in A \text{ para cada } b \in B\}$$

The figure 5 shows the block diagram for the obtaining of the exudates segmentation, and the figure 6 shows the block diagram for the obtaining of the hemorrhages segmentation.

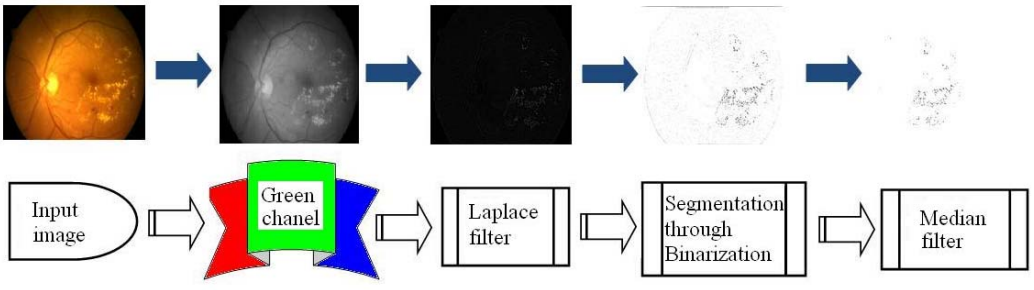

Figure 5: Block Diagram of the proposed method for the hemorrhages obtaining.

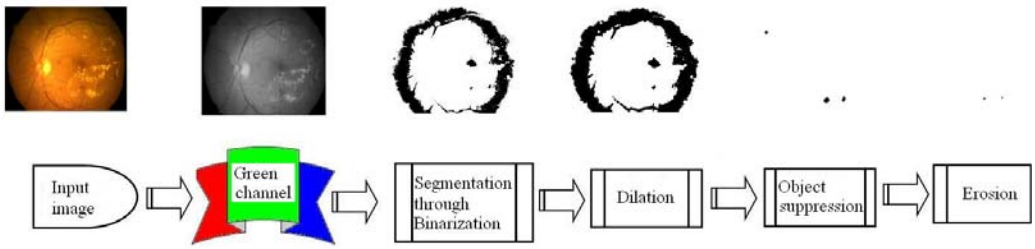

Figure 6: Block Diagram of the proposed method for the exudates obtaining.

3 Experiments and Results

The images used here were obtained by the study's result of Fluorescein angiography applied on patients who are suffering diabetic retinopathy. The image repository consists of 25 images, each with a size of 768 x 576.

For each image was considered the green canal as is described by the method to work with the image in grayscale. For the exudates segmentation was applied the Gaussian Laplacian filter with the figure 7 mask. The figure 8 shows an image in grayscale and the same image after the application of the Laplacian of Gaussian filter with the given mask.

For the segmentation by binarization was used the thresholds of 50-200. For the hemorrhages segmentation was used segmentation by binarization with thresholds of 55-80, for the dilatation and erosion was used the cruciform structuring element 5 x 5 sized as the figure 9.

The figure 10 shows an images set divided in three columns, in the first is displayed four images taken from the repository, in the second is displayed the exudates segmentation of each image from the column 1 respectively, and in the third is displayed the exudates segmentation on overlaying the original image.

The figure 11 shows a set of images divided in three columns, the first displayed four images taken from the repository, the second displays the hemorrhage segmentation of each image from the column 1 respectively, and in the third is displayed the hemorrhages segmentation on overlaying the original image.

0	0	-1	0	0
0	-1	-2	-1	0
-1	-2	16	-2	-1
0	-1	-2	-1	0
0	0	-1	0	0

Figure 7: Mask used in the Laplacian of Gaussian.

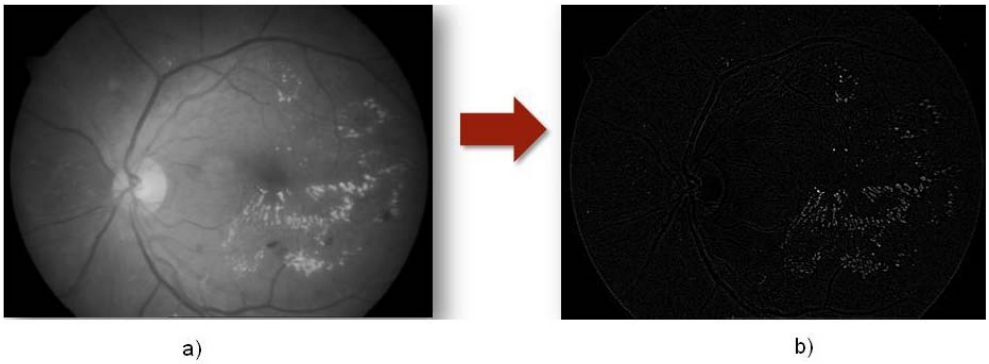

Figure 8: In a) A grayscale image and in b) After applied the Laplacian of Gaussian filter.

0	0	1	0	0
0	0	1	0	0
1	1	1	1	1
0	0	1	0	0
0	0	1	0	0

Figure 9: Structuring element used to erode and dilate.

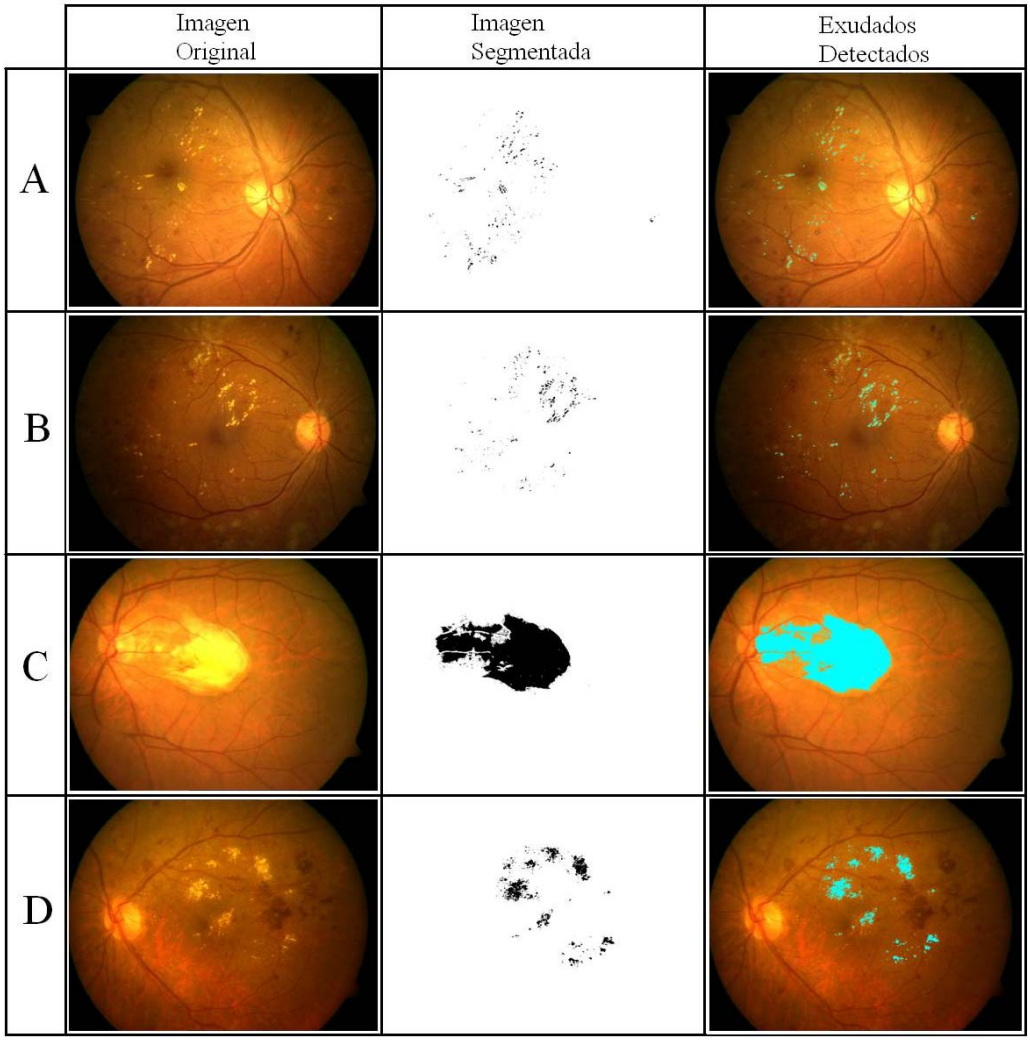

Figure 10: Displays four images. Original image, segmentation of exudates and exudates on overlaying the original image.

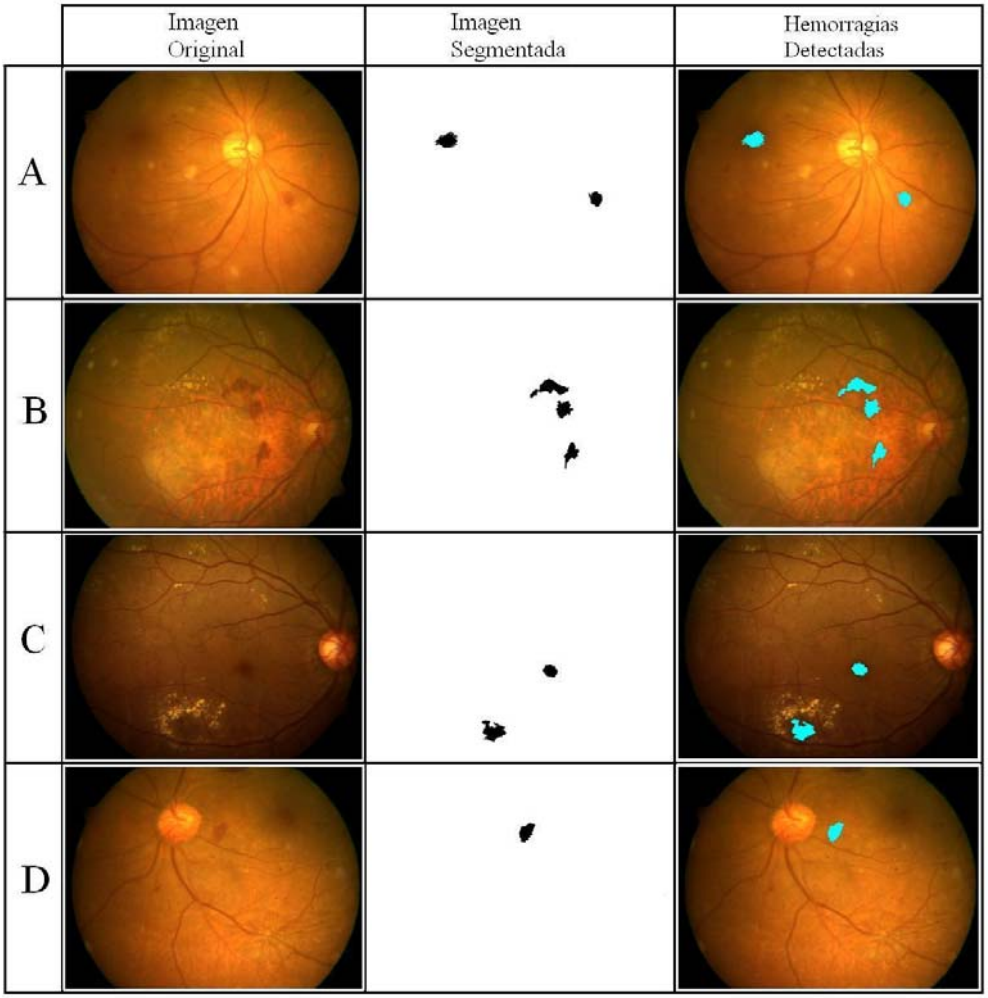

Figure 11: Displays four images. Original image, segmentation of bleeding and bleeding overlaying on the original image.

4 Conclusion

In this paper was showed an automated method for the detection of exudates and hemorrhages which are present in retinal vascular network images of patients who suffer diabetic retinopathy. The images were obtained from patients who were subjected by the Fluorescein angiography study. A total of 25 images 768 x 576 sized are the repertoire.

In the exudates segmentation case was used the image in grayscale, and was

applied the Laplacian filter, followed of the segmentation by binarization, and the median filter. In the hemorrhages segmentation case was used the image in grayscale too, and was applied segmentation by binarization, dilatation, remove of objects and finally the erosion operation. As can be seen in the images of figures 10 and 11, was obtained satisfactory results when was applied the methodology on the images used in the fluorescein angiography study. This paper can be useful as base to those research papers which will use Artificial Vision and which are related with the diabetic retinopathy disease.

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