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Digital tool for detecting diabetic retinopathy in retinography image using gabor transform

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Abstract. Diabetic retinopathy is a chronic disease and is the leading cause of blindness in the population. The fundamental problem is that diabetic retinopathy is usually asymptomatic in its early stage and, in advanced stages, it becomes incurable, hence the importance of early detection. To detect diabetic retinopathy, the ophthalmologist examines the fundus by ophthalmoscopy, after sends the patient to get a Retinography. Sometimes, these retinography are not of good quality. This paper show the implementation of a digital tool that facilitates to ophthalmologist provide better patient diagnosis suffering from diabetic retinopathy, informing them that type of retinopathy has and to what degree of severity is find. This tool develops an algorithm in Matlab based on Gabor transform and in the application of digital filters to provide better and higher quality of retinography. The performance of algorithm has been compared with conventional methods obtaining resulting filtered images with better contrast and higher.

1. Introduction

Diabetic retinopathy is a complication ophthalmological of the diabetes. This is caused by deterioration of blood vessels that nourish the retina. This weakening of blood vessels may cause dilation of the vascular wall, leading to extravasation of fluid such as blood plasma and as a final result the appearance of bleeding [1].

Imaging techniques are based on the development of systems capable of detecting different physical signals emitted by the body or organ object study, and that are imperceptible to humans. Once detected, the own system the signals into data which, when processed in turn, allow the formation of an image. Against this background, it has been doing for the past 20 years, a large research to optimize existing technologies, and develop new medical imaging techniques [2].

The progress of medical imaging techniques is very diverse, from areas where research is still at a very conceptual level, to fields where there are well developed prototypes that are used in medical research, but not yet part of the clinical routine for various reasons, or techniques used with success in clinical practice, but has not extended its use for other applications [3].

This paper provides a technique related to computational analysis of the ophthalmoscopic images (retinography), with the aim of making improvements to those images by applying Gabor transform and
digital filters that allow you to have higher quality and better viewing. What would enable ophthalmologists perform an analysis more detailed about the possible conditions that affect their patients, especially in our case study, diagnose "diabetic retinopathy."

The Gabor function has been used extensively in texture segmentation [4] and defect detection [5], as it can be tuned to a specific frequency and orientation, and achieve both localization in the time domain and frequency domain; two-dimensional (2-D) Gabor filters are multi-channel filters with a multi-resolution decomposition process, which is similar to wavelet analysis. Time-frequency analysis, such as the Gabor transform, plays an important role in many signal processing applications. In harmonic analysis the algorithms of Fourier transformation are often applied [6,7]. However, this method gives significantly better results for stationary systems where frequency composition does not change during the investigation.

A fair amount of research papers have been published in literature for Gabor filter-based image processing [8,9]. Besides face recognition, Gabor filters are successfully used in many other images processing and analysis domains, such as: image smoothing, image coding, texture analysis, shape analysis, edge detection, and fingerprint and iris recognition. In this paper show the implementation of a digital tool that facilitates to ophthalmologist provide better patient diagnosis suffering from diabetic retinopathy, informing them that type of retinopathy has and to what degree of severity is find. This tool develops an algorithm in Matlab based on Gabor transform and in the application of digital filters to provide better and higher quality of image retinography.

2. Methodology

2.1 Design

The images are acquired by a retinograph that takes a picture of the fundus. The retinograph we use for testing is the TRC50DX, consisting of a digital camera of high resolution 12.1 and 16 megapixels to color, which it allows to observe the details of the fundus, storing and transferring to a computer. Here these images are converted to grayscale and segmented. ‘Figure 1’

![Figure 1. Block Diagram of the system design](image)

The proposed algorithm for the detection of frequency hopping signals, perform processing of the signal segment in four stages: In the first stage, the image and the Gabor transform are defined; in the second stage the Fourier transform is computed for the image and Gabor surface; in the next stage, the convolution of the Fourier transforms is developed, and finally in the next stage the Gabor transform of the image is allowed and the skeletonization of image is finally obtain [10]. ‘Figure 2’
The database images were taken from Kuopio University Hospital and the eye clinic of the Doctor Flavio Piñeres, who is ophthalmologist that helped in the classification of the same.

2.2 Implementation

2.2.1 Gabor Transform

Gabor transform was first defined by Gabor [10-13] and later extended to 2-D. In the spatial domain, the Gabor function is a Gaussian curve with aspect ratio modulated by a complex sinusoid; the Gabor filter was originally introduced by Dennis Gabor. The one-dimensional Gabor filter is defined as the multiplication of a cosine/sine (even/odd) wave with a Gaussian window as follows:

\[ g_e(x) = \frac{1}{\sqrt{2\pi\sigma}} e^{-\frac{x^2}{2\sigma^2}} \cos(2\pi\omega_0 x) \quad (1) \]

\[ g_o(x) = \frac{1}{\sqrt{2\pi\sigma}} e^{-\frac{x^2}{2\sigma^2}} \cos(2\pi\omega_0 x) \quad (2) \]

Where \( \omega_0 \) defines the centre frequency (i.e., the frequency in which the filter yields the greatest response) and \( \sigma \) the spread of the Gaussian window. Daugman extended the Gabor filter to two dimensions as follows:

\[ g_e(x, y) = \frac{1}{2\pi\sigma_x\sigma_y} e^{-\left(\frac{x^2}{\sigma_x^2} + \frac{y^2}{\sigma_y^2}\right)} \cos\left(2\pi\omega_0 x + 2\pi\omega_0 y\right) \quad (3) \]

\[ g_o(x, y) = \frac{1}{2\pi\sigma_x\sigma_y} e^{-\left(\frac{x^2}{\sigma_x^2} + \frac{y^2}{\sigma_y^2}\right)} \sin\left(2\pi\omega_0 x + 2\pi\omega_0 y\right) \quad (4) \]

Where \( \omega_{x_0}, \omega_{y_0} \) defines the centre frequency and \( \sigma_x, \sigma_y \) the (potentially asymmetric) spread of the Gaussian.

The Gabor filter represents a band-pass linear filter whose impulse response is defined by a harmonic function multiplied by a Gaussian function. Thus, a bidimensional Gabor filter constitutes a complex sinusoidal plane of particular frequency and orientation modulated by a Gaussian envelope [14]. It achieves an optimal resolution in both spatial and frequency domains. ‘Figure 3’
3. Results

From the image processing point of view, many strategies and algorithms have been developed to deal with the extraction of the retinal vessel tree. An automatic segmentation of the vasculature could save workload of the ophthalmologists and may assist in characterizing the detected lesions and to identify false positives. The filters used in the test images are filters that are predetermined in matlab such as Laplacian, Prewitt, Sobel, Sharpen, among others, which finally did not produce the expected results. ‘Figure 4’

For this reason, they continued testing with other filters that serve as a basis for designing a new one that would allow us to get a better picture. Among these is the canny filter and filter gabor. The Gabor filter is one efficient method for automatic segmentation of retinal blood vessels [15]. ‘Figure 6’

One of the drawbacks that occurs during the analysis of the Retinography is the optical disk, for this reason we use transforms Hung to differentiate and exclude it from our analysis. ‘Figure 8’
It has designed a graphical interface called "Computer Aided System for Early Detection of Diabetic Retinopathy" which it has two formularies, one gives it to the ophthalmologist the option to manually analyse the image; and the other it is of the software, which it is able to analyse and give their own diagnosis. This must be validated by the health professional.

In these figures are showing the final analysis made by the software. In they are showing the detection of the regions and the possible anomalies in the different quadrants. This digital tool can to perform its own diagnostic; in this case the patient has severe diabetic retinopathy. This result was validated by the ophthalmologist.

4. Conclusion

It has developed a digital tool that detects in a Retinography if a patient has diabetic retinopathy and to what degree is this. The Gabor filter is one efficient method for automatic segmentation of retinal blood vessels. This filter is implemented in Matlab. It is a powerful tool when processing digital images and this application is a proof, since it was used to make a software that helps the ophthalmologist to diagnose diabetic retinopathy. In this application you only need one retinography image and then be processed in Matlab, where it has carried out different routines to adjust the image so that it can display the constituent parts of the eye and those found to be of interest when giving an assessment. This tool
does not replace the ophthalmologist, but on the contrary was developed as an aid to diagnosis of diabetic retinopathy.

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