DEVELOPMENT AND EVALUATION OF ADVANCED RETINAL IMAGING PLATFORM FOR BIOMEDICAL ENGINEERING EDUCATION

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Abstract: A problem of fundamental importance in retinal image analysis is the extraction of blood vessels and the detection of the Optic Disk (OD). Our work introduces two techniques that detect blood vessels based on morphological operators and one technique for the OD detection based on the 'snakes' method. Our purpose was to create a computer-based image-processing and analysis tool for extraction of blood vessels and optic disk in the retinal images, which will be easy to use and helpful for the educational work of the physicians in diagnosing ocular diseases, patient screening, clinical study and the biomedical engineering students.

Introduction

A lot of people nowadays suffer from ophthalmological problems (figure 1), especially retinal ones. Retinopathy is one of the most common causes of blindness in modern world. An accurate and early diagnosis from well educated specialists can prevent blindness more than 50% of all cases [11]. It is very important for a clinician to be well educated and have advanced tools in order to detect retinal pathologies. It is also important for an engineer to develop certain tools that can help the clinician in his/her work. Our purpose was to create an advanced retinal imaging Matlab® platform with effective techniques, for the extraction of blood vessels and the detection of the Optic Disk (OD) boundary helping the ophthalmologists in speciality and the biomedical engineering students in imaging courses [1,2].

Materials and Methods

In this paper we developed two techniques for the extraction of blood vessels: the Adaptive Filtering and the Tophat Filtering [9,10]. The original image is convolved with a Gaussian filter and the edges are enhanced. The convolution of the enhanced image with the Wiener filter forms the Adaptive Filtering. Then morphological mathematical operators are used to create the Tophat Filtering. Finally, the false edges, for both techniques are suppressed using the threshold-hysterisis method. As for the OD detection, Sinthanayothin [3], Li and Gutatape [1,4], Lalonde [5], Walter and Klein [6] and others suggested different methods. However, the most efficient methods were addressed by Mendels [2] and improved by Osareh [7] based on active contour models or 'snakes' [8]. This technique needs morphological pre-processing and requires initialization. This means the drawing of the OD boundary by an expert. Then the coordinates of the initial boundary alter according to internal and external elastic forces. The force parameters and the number of iterations are pre-defined. The above steps are shown in figure 3.

We tested the effectiveness and robustness of the vessel extraction techniques defining the parameters:

$$Se = \frac{TP}{(TP + FN)} \quad (1)$$

$$CV = \frac{\sigma}{Se_{\max}} \quad (2)$$

Se is the sensitivity of the method according to specific Gaussian σ value, Se_{max} the maximum Se value, TP the number of blood vessels that are correctly detected by a physician, FN the number of blood vessels that are shown on the original image but are not correctly detected and σ the standard deviation value of the Gaussian filter used. The CV value depicts statistical homogeneity.

Testing the 'snakes' method we defined the error of the area and the perimeter in pixels before and after being the OD boundary traced as:

$$Area(error) = \frac{\sum (area_{initial} - area_{final})}{M} \quad (3)$$

$$Perimeter(error) = \frac{\sum \text{perimeter}_{\text{initial}} - \text{perimeter}_{\text{final}}}{\text{M}} \quad (4)$$

Where M is the number of images tested. The user has no interaction with the Matlab® code. The platform based on a GUI (Graphics User Interface) allows the user to choose the desirable technique from a pop-up menu as shown in figure 2.

The blood vessel extraction algorithms are applied to 38 retinal images, normal and pathological ones, using several values of the standard deviation parameter

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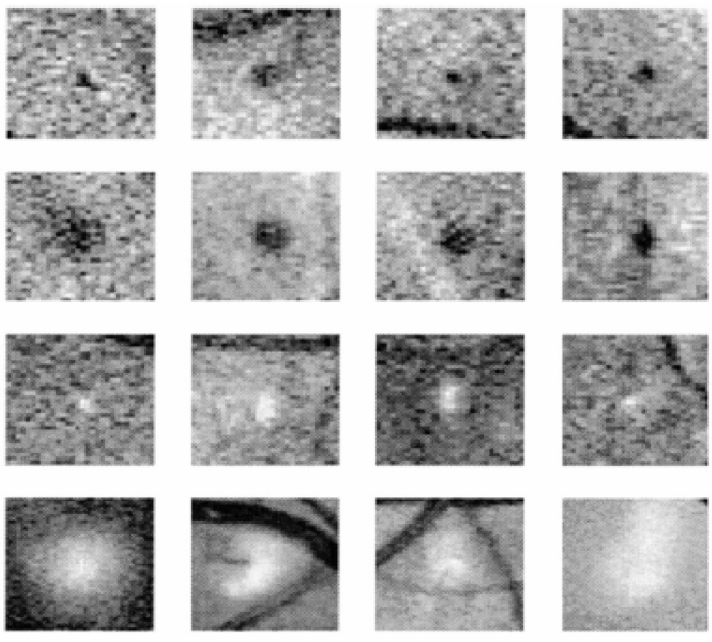

Figure 1: Examples of microaneurysms (row 1), haemorrhages (row 2), exudates (row 3) and cotton wool spots (row 4)

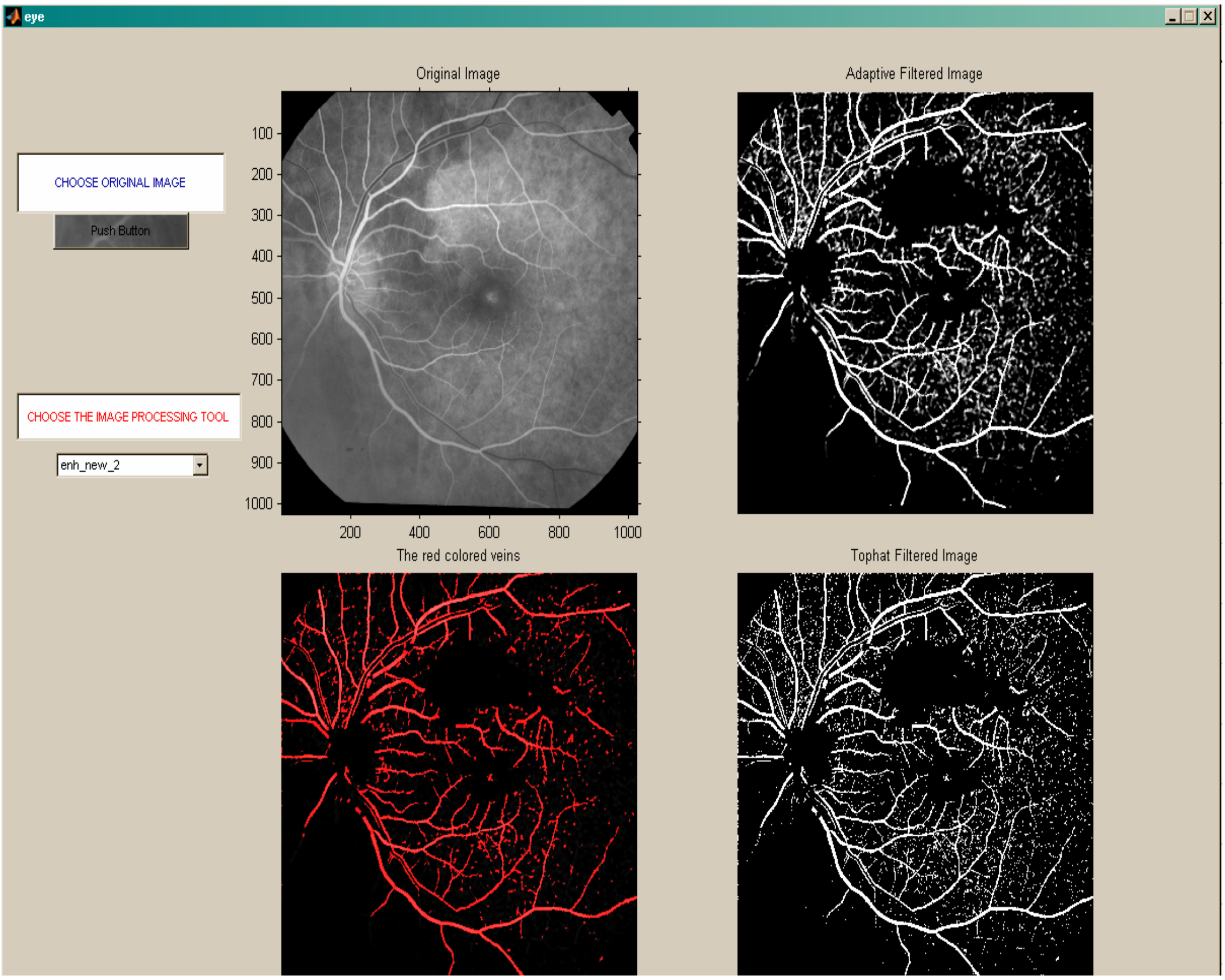

Figure 2: Example of the retinal imaging Matlab® platform

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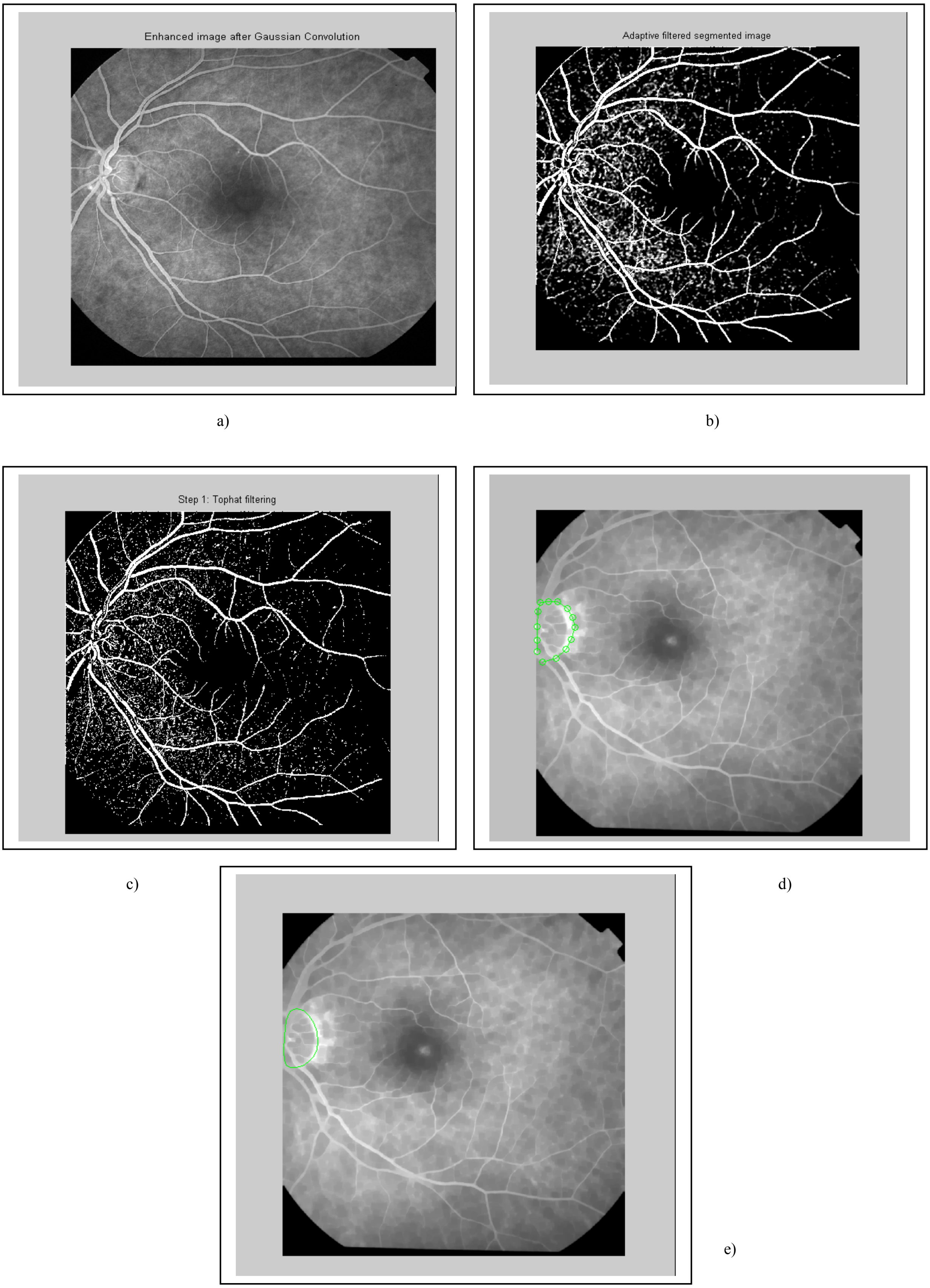

Figure 3: (a) Edge-Enhanced original image, (b) The blood vessels extraction using the Adaptive Filtering, (c) The blood vessels extraction using the Tophat Filtering, (d) Initialization of the OD detection technique, (e) Final result of the OD detection technique

σ of the filters. In order to reach safe conclusions and more over to compare the two techniques we calculated the quantity: $Se = \frac{TP}{TP + FN}$. Finally we calculated the quantity $CV = \frac{\sigma}{Se_{\max}}$.

Results

The blood vessel extraction techniques were applied to 38 different retinal images, normal and pathological ones. We proved that both the Adaptive and the Tophat Filtering techniques are independent of the σ value, maintaining high $Se \approx 0.80$. The techniques are equally efficient for clear and blurred images. The CV value is slightly over 10% for both techniques, while the Adaptive Filtering shows more homogeneity than the Tophat Filtering.

The OD detection algorithm was applied to 41 images of ocular fundus. We proved that the 'snakes' method is sensitive to the initialization. The area and perimeter errors are quite small. We estimated the errors and the results were: For the Area (error) equals to 0.304 and for the Perimeter (error) equals to 4.856×10^{-3}. This means that the OD traced by the algorithm is very similar to the original, no matter the OD true dimensions and the difference of the brightness between the OD region and the image background.Moreover, we concluded that our technique is quite effective by calculating the error of the area and the perimeter before and after being the OD traced by the algorithm.

By reaching a good standard of the image anaylsis techniques with clinically accepted results, we developed a Matlab platform, incorporating all the described techniques. This platform is shown in the figure 2.

Discussion

Our methods are independent of the σ value, equally to clear and blurred images. However, all the initializations where made by human experts and this fact makes our techniques “weak”. All the above methods can be used both to gray-scale and color images. In addition, they can be loaded in a Graphics User Interface (GUI)-platform, so that the clinician is able to choose the appropriate technique. This helps the educational work of ophthalmologists-medical students in speciality and biomedical engineering students.

Conclusions

Digital imaging is becoming available as means of screening for retinopathy. We have described the development of a tool to provide analysis of digital images taken as part of routine monitoring of retinopathy, supporting the education of clinicians and engineers. Our tool is a platform that has been very useful for conducting experiments for the blood vessel extraction and the optic disk detection. Today, a huge amount of the western population suffers from retinal pathological problems. The appropriate education of the clinical personnel with the help of the digital technology means more accurate diagnoses and better treatment. The platform constructed and the techniques developed are used to assist clinicians in Ophthalmology and biomedical engineering students.

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