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Proyecto: "Detección automática de retinopatía diabética utilizando algoritmos neuro-evolutivos" **Código:** PINV18-846

Fundus image enhancement

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Overview

Introduction

Retinal images are widely used for diagnosis and eye disease detection. However, due to the acquisition process, retinal images often have problems such as low contrast, blurry details or artifacts. These problems may severely affect the diagnosis. Therefore, it is very important to enhance the visual quality of such images. Contrast enhancement is a pre-processing applied to images to improve their visual quality. This technique betters the identification of retinal structures in degraded retinal images. In this work, a novel algorithm based on multi-scale mathematical morphology is presented.

Basic concepts

Top-Hat transform is defined from morphological operations of dilation, erosion, opening and closing. Such operations are defined as follows:

Dilation and Erosion: These are the basic operations of mathematical morphology. They are defined as:

$$\delta_B(I)(u,v) = \max_{(x,y)\in B}(I(u-x, v-y)), \tag{1}$$

$$\varepsilon_B(I)(u,v) = \min_{(x,y)\in B}(I(u+x, v+y)), \tag{2}$$

Basic concepts

Opening: To make the opening, first the image is eroded and secondly it is dilated using the same structuring element. Morphological opening is defined as:

$$\gamma_B(I) = \delta_{\check{B}}(\varepsilon_B(I)), \tag{3}$$

where $\check{B}$ is the reflection of B.

Closing: To make the closing, first the image is dilated and then it is eroded using the same structuring element. Morphological closing is defined as:

$$\phi_B(I) = \varepsilon_{\check{B}}(\delta_B(I)). \tag{4}$$

A structuring element is symmetrical if it is equal to its reflection, i.e. $B = \check{B}$.

Basic concepts

Based on previous definition two Top-Hat operations can be defined:

White Top-Hat (WTH): This is used to obtain the bright regions lost in the morphological opening. WTH is defined as:

$$WTH_B(I) = I - \gamma_B(I), \tag{5}$$

where I is the original image, B is the structuring element and $\gamma_B(I)$ is the morphological opening.

Black Top-Hat (BTH): This is used to obtain the dark regions lost in the morphological closing. BTH is defined as:

$$BTH_B(I) = \phi_B(I) - I, \tag{6}$$

where I is the original image, B is the structuring element and $\phi_B(I)$ is the morphological closing.

Basic concepts

Finally, the Open-Close Close-Open (OCCO) is introduced. It is applied intro an image to reduce noise. It is defined as:

$$OCCO_B(I) = \frac{1}{2}\gamma_B(\phi_B(I)) + \frac{1}{2}\phi_B(\gamma_B(I)). \tag{7}$$

Proposed algorithm

Algorithm 1 Open-Close Close-Open - Multi-scale Top-Hat for retinal image enhancement (OCCO-MTH)

Input: I: Original image, B: Structuring element B, G: Structuring element G, n: Number of iterations, ω: Contrast adjustment weight.

Output: I_E *(Enhanced image)*

Initialisation : B, G, n, ω

1: *Noise removal with OCCO filter* (Equation 7)
$OCCO = OCCO_B(I)$

2: **for** $i = 1$ to n **do**

3: *Multi-scale Top-Hat transform*
$TH_i = WTH_{G_i}(OCCO)$,
$BH_i = BTH_{G_i}(OCCO)$,

4: **end for**

5: *Calculation of the maximum areas of brightness and darkness.*
$MTH = \max_{1 \leq i \leq n}\{TH_i\}$,
$MBH = \max_{1 \leq i \leq n}\{BH_i\}$.

6: *Image enhancement calculation.*
$I_E = I + \omega \times MTH - \omega \times MBH$,

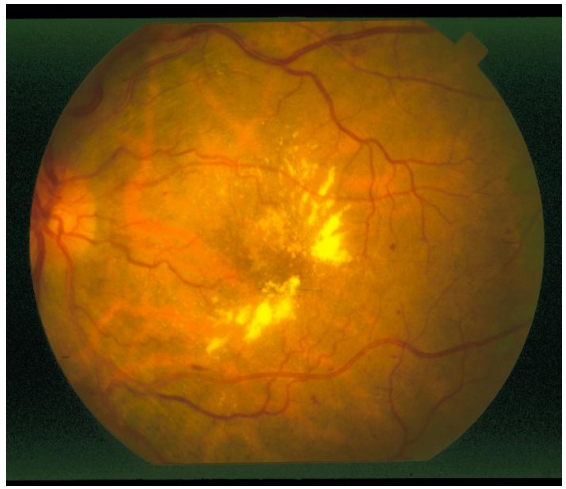
7: **return** I_E

Initial parameters

Original image I, the structuring element B disk with radius $r = 1$, the initial structuring element G disk with radius $r = 1$ which increases in a range of $i = \{1, ..., n\}$, the number of iterations $n = 10$ and $\omega = 1.5$ is the contrast adjustment weight. All the algorithms were implemented in MATLAB R2014a. HE does not use parameters and CLAHE uses a default configuration.

Visual analysis

[Original] 

[HE] 

[CLAHE] 

[OCCO-MTH] 

Figure: Images with severe diabetic nonproliferative retinopathy.

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Numerical results

Table: Average results of the 397 retinal images processed with the HE, CLAHE, MTH and OCCO-MTH algorithms.

Algorithms	E	PSNR	SSIM
HE	5.821	17.128	0.777
CLAHE	**7.705**	18.175	0.820
OCCO-MTH	7.175	**32.115**	**0.895**

Conclusions

In this work, a novel retinal image enhancement algorithm was proposed. The numerical and visual results show contrast enhanced retinographies, similarity to the original image and low distortion with respect to the compared algorithms.

Thank you for your time