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Image enhancement with mean brightness preservation based on multiscale top-hat transform

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Abstract. Multiscale mathematical morphology is a technique used to improve the visual quality of images. These techniques generally introduce distortions in the process of improvement that cause loss of brightness in the images. In this work a method of contrast improvement and brightness preservation is presented. The method is based on the multiescale top-hat transform. In the top-hat transform two structuring elements of different areas are used, but of similar and flat structures. The evaluation of the proposed method was carried out using 200 images from a public database. The comparison of the proposal was made with other state of the art methods. Numerical and visual results show images with contrast enhancement, natural brightness and moderate distortions.

Keywords. Multiscale mathematical morphology, multiescale top-hat transform, structuring elements, contrast enhancement, natural brightness

1 Introduction

Contrast enhancement in digital images is an important technique in image processing. This image enhancement technique helps human vision to better value details [15]. Moreover, it is used as a preprocessing for other applications that need to enhance image quality.

Contrast enhancement techniques can be classified in different ways. Currently there are many proposals in the state of the art. There are algorithms that enhance contrast [2, 19], enhance color images [18] and others that enhance grayscale images with noise [10,12]. Histogram-based enhancement algorithms are widely used to enhance the brightness zones

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of an image, but they can introduce saturation into the image [1, 2, 9, 17, 23]. Filters are generally used to improve images with noise [10, 12]. Algorithms in the wavelet domain [11,22] improve image resolution. Mathematical morphology is a widely used tool in image processing [13] and uses morphological operators to extract different types characteristics of the image, which can be used to perform an image enhancement.

In mathematical morphology the top-hat transform is used as one of the main operations for contrast enhancement. Image enhancement by top-hat transform consists of adding bright areas and subtracting dark areas of the original image. The multiscale top-hat transform has been shown to be efficient in improving grayscale images [6, 15]. They are also useful in multiple applications such as retina study [14], ultrasound image enhancement [16], infrared image enhancement [4,20], image fusion [7,25] and small object detection [24].

The purpose of image enhancement is to enhance features such as brightness, darkness, shapes, etc., in the images. The multiscale top-hat transform can enhance the useful features of the image which will then be used to enhance the image [4, 6, 15, 19, 20]. The aim of this work is to improve the image in terms of contrast and preserve the natural brightness of the images. For this reason, we propose a method to improve the image using the multiscale top-hat transformation using two structuring elements. The novelty of the proposal is that two structuring elements are used in the basic operations of mathematical morphology [19]. However, by adding this variation it is possible to improve the contrast of the images, improve the mean brightness and introduce distortions in a moderate way.

The work is organized as follows: Section 2 presents the proposed image improvement, Section3 shows the numerical and visual results and finally Section 4 presents the conclusion of the proposed method.

2 Proposed method to image enhancement

The top-hat transform is a mathematical morphology operation that is used to make improvements in digital images [21]. It is widely used in different applications such as medicine [14, 16] and engineering [4, 7]. The top-hat transform is defined as follows:

$$WTH = I - (I \ominus B) \oplus B, \tag{1}$$

$$BTH = (I \oplus B) \ominus B - I. \tag{2}$$

where WTH is the top-hat transform by opening, BTH is the top-hat transform by closing, $(I \ominus B) \oplus B$ is the morphological opening, $(I \oplus B) \ominus B$ is the morphological closing, $\ominus$ and $\oplus$ are morphological operators of erosion and dilation. The bright areas are obtained by WTH and the dark areas are obtained by BTH.

The classic top-hat transform uses only one structuring element. In order to improve its performance, two structuring elements are proposed [5]. For this reason, we will use two proportional and flat structuring elements in the top-hat transform.

Let the structuring elements be G and $G^{'}$ geometrically proportional and flat. Taking into account the two increasing structuring elements, the top-hat transform is finally defined as follows [19]:

$$WTHN = I - ((I \ominus G) \oplus G^{'}), \tag{3}$$

$$BTHN = ((I \oplus G) \ominus G^{'}) - I. \tag{4}$$

Equations 3 and 4 will be used to perform image enhancement within the scheme using the multiscale top-hat transform.

The image enhancement by the multiscale top-hat transform will be performed by initially configuring the following parameters: The original image I, the number of iterations n in the range $i = 1, 2, \cdots n$ and the two structuring elements G and $G^{'}$. The characteristics of the structuring elements are: square and flat.

The image enhancement process is then described in the following Algorithm 1.

Algorithm 1 Image Enhancement Algorithm

Input: I, G, $G^{'}$, n
Output: I_E *(Enhanced image)*
Initialisation : G, $G^{'}$
1: **for** $i = 1$ to n **do**
2: *Calculation of top-hat transform.*
$WTHN_i = I - ((I \ominus G_i) \oplus G_i^{'})$
$BTHN_i = ((I \oplus G_i) \ominus G_i^{'}) - I$
3: *Calculation of subtractions from neighboring scales, obtained through the top-hat transform.*
$WTHN_{i-1}^S = WTHN_i - WTHN_{i-1}$,
$BTHN_{i-1}^S = BTHN_i - BTHN_{i-1}$
4: **end for**
5: *Calculation of the maximum values of all the multiple scales obtained.*
$WTHN_M = \max_{1 \le i \le n} WTHN_i$,
$BTHN_M = \max_{1 \le i \le n} BTHN_i$,
$WTHN_M^S = \max_{1 \le i \le n-1} WTHN_{i-1}^S$,
$BTHN_M^S = \max_{1 \le i \le n-1} BTHN_{i-1}^S$
6: *Image enhancement calculation.*
$I_E = I + (WTHN_M + WTHN_M^S) - (BTHN_M + BTHN_M^S)$
7: **return** I_E

In the following section we present the experimental results obtained from comparing the proposed method with other algorithms of the literature.

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3 Results and discussions

The relative performance of the proposed method was compared with the Histogram Equalization (HE), Contrast Limited Adaptive Histogram Equalization (CLAHE) [26] and Multiscale Morphological Contrast Enhancement (MMCE) [6] algorithms. The evaluation of the results was carried out using Standard Deviation (SD) [19] that quantifies the global contrast of the images, Contrast Improvement Ratio (CIR) [20] that quantifies the local contrast of the images, Peak Signal to Noise Ratio (PSNR) [19] that quantifies the relationship between the signal-noise introduced in the image enhancement process and Absolute Mean Brightness Error (AMBE) [2] that quantifies the conservation of the mean brightness of the processed image.

For the tests, 200 images from the test folder belonging to the public database BSDS500 [3] were used. The tests for the HE and CLAHE algorithms were performed using a MATLAB program [26]. The parameters used for the CLAHE were by default. The MMCE and the proposal algorithms were implemented by the ImajeJ framework [8].

The parameters for the MMCE were the original image I, $n = 10$ and the initial 3×3 size square B structuring element. The parameters for the proposal were the original image I, $n = 8$ and the square initial structuring elements G and G' of sizes 3×3 and 21×21. The structuring elements in each iteration increase in steps of two.

In Table 1 we can see that on the average, the MMCE algorithm is numerically better for the PSNR evaluator, however the proposal in the average obtained better results for the SD, CIR and AMBE evaluators. The best average results are in bold.

Table 1: Average of the evaluations of the 200 grayscale images obtained with HE, CLAHE, MMCE algorithms and proposed method.

Methods	n	SD	CIR	PSNR	AMBE
I	-	50.856	-	-	-
HE	-	73.396	2.246	16.268	28.775
CLAHE	-	62.455	2.107	16.171	20.352
MMCE	10	72.899	16.281	**17.798**	3.819
Proposal	8	**75.747**	**16.984**	16.633	**3.804**

In Figure 1 we can see the (a) original image *156054.jpg*, (b) enhanced image with HE, (c) enhanced image with CLAHE, (d) enhanced image with MMCE and (e) enhanced image with the proposed method. Visually, we can see that the HE algorithm introduces more brightness to the image, CLAHE slightly improves contrast, MMCE improves contrast, preserves mean brightness and distorts the image, while the proposed method better preserves the mean brightness, improves contrast and introduces distortions in a moderate way.

(a) Original Image (b) Image enhanced with HE (c) Image enhanced with CLAHE (d) Image enhanced with MMCE (e) Image enhanced with proposed method

Figure 1: Visual results of experiment

4 Conclusion

In this work, a proposed method was presented that uses multiscale mathematical morphology to make the enhancement in an image. The extraction of brightness and dark characteristics of an image was done with the multiscale top-hat transform, which uses two geometrically proportional and flat structuring elements. The relative efficiency of the proposed method was assessed with: Standard Deviation (SD), Contrast Improvement Ratio (CIR), Peak Signal to Noise Ratio (PSNR) and Absolute Mean Brightness Error (AMBE).

Numerically, the proposed method presents better performance for SD, CIR and AMBE, compared to the HE, CLAHE and MMCE algorithms. In general, this shows that the images obtained with the proposed method present low distortion, preserve their natural brightness and also enhance the contrast of the original images. The advantage of the proposal is that it allows us to configure the size and shape of the structuring elements. From this we can choose what kind of enhancement we want to make to an image.

For future works, we intend to test the algorithm with specific image databases such as radar, infrared, astronomical and other images.

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