ENHANCEMENT OF UNEVEN LIGHTING TEXT IMAGE USING LINE-BASED EMPIRICAL MODE DECOMPOSITION

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ABSTRACT

Non-uniform light distribution problems often arise in the text images taken by digital camera. In this paper, we propose a novel technique for text image uneven lighting removal using Empirical Mode Decomposition (EMD). The EMD is local, adaptive and useful for analyzing non-linear and non-stationary signals. In this method, we decompose images by EMD and get the background level locally and adaptively. This algorithm can enhance local contrast in the image while removing shadows for black-and-white text images. In addition, this work can be very helpful for text recognition. The experimental results show that the proposed approach can effectively enhance text images more readable under uneven lighting.

Index Terms—EMD, Image enhancement, Uneven lighting removal, Image processing

1. INTRODUCTION

With the digitization of the scientific and technological products in recent years, more and more devices need the image processing skill, no matter in digital still camera (DSC), cell-phone, projector, printer, liquid crystal TV, LCD, video presentation systems (VPS), etc., they all need to show good-looking images. DSC is used to take pictures just like the conventional film camera. People prefer digital camera over traditional camera for its convenience nowadays. However, in many situations, the camera is unable to work well under darker environment or unequal light source. Unlike DSC, the VPS is usually used to show a text document and then project the text content to a wide screen. Fig. 1 shows a text image with shadow in its right side because the source luminance is located at left. Due to the non-uniform light distribution, we can’t see the details clearly and it is difficult to read the text in the shadow of the images. In [10], the authors proposed a method called SIBT to enhance the quality of degraded text-photo images, other similar methods can be found in the references of [10]. However, their algorithms are too complicated and not easy to be implemented. In this paper, we propose a novel and simple method based on EMD to improve the issue of non-uniform light distribution for text images. EMD is a powerful method for generating adaptive multiscale structure of non-stationary signals and analyzing them [1][2][3]. There are several variations of EMD algorithms introduced in [4]. This paper is organized as follows. Section 2 describes the algorithm of EMD. Section 3 presents the proposed technique for text image enhancement. Experimental results and comparison with other methods are shown in Section 4. Finally, conclusions are made in Section 5.

2. EMPIRICAL MODE DECOMPOSITION

The EMD is first introduced by Huang et al. [1] for signal processing. This novel tool decomposes non-linear or non-stationary signals into frequency components called IMFs. IMFs must satisfy the following two conditions:
• the numbers of extrema and the numbers of zero-crossings must either equal or differ at most by one in whole data set.
• at any point, the mean value of the envelope defined by the local maxima and the envelope defined by the local minima is zero.

The process of extracting an IMF from a signal is called the sifting process introduced in [1]. For a real-valued signal \( f(t) \), we can extract IMFs from it by the following steps:
1) Initialize \( h_0(t) = r_0(t) = f(t), i=j=1; \)
2) Identify all local maxima and minima of \( h_{j-1}(t) \);
3) We generate the upper envelope by interpolating the local maxima, denoted \( h_{\text{upper}}(t) \), and the lower envelope by interpolating the local minima, denoted \( h_{\text{lower}}(t) \);
4) Compute the envelope mean, \( m_{j-1}(t) = (h_{\text{upper}}(t) + h_{\text{lower}}(t))/2 \);
5) Compute \( h_j(t) = h_{j-1}(t) - m_{j-1}(t) \);
6) Repeat steps 2-5 and set \( j = j+1 \) until \( h_j(t) \) is an IMF;
7) \( \text{imf}_i(t) = h_j(t) \) and compute the \( i \)-th residue \( r_i(t) = r_{i-1}(t) - \text{imf}_i(t) \);
8) Repeat steps 2-7 and set \( i = i+1 \) until \( r_i(t) \) is monotonic. When \( r_i(t) \) is monotonic, we have accomplished the EMD, and set \( r_L(t) = r_i(t) \).

The original signal \( f(t) \) can be expressed as the sum of IMFs and the last residue as follow:

\[
f(t) = \sum_{i=1}^{L} \text{imf}_i(t) + r_L(t)
\]

3. PROPOSED ALGORITHM FOR TEXT IMAGES

Since text document is often printed in black over white paper and the ratio of black pixels to white pixels is not influenced badly by the light source, the light source influences the text and background both. We want to estimate the ratio of text to background level and then adjust the background level to white. The EMD can decompose a signal into several IMFs and a final residue. The final residue is a monotonic slope. However, we may not necessarily need the final residue to represent background level. Therefore, we do not do the sifting process until the residue is monotonic and only do 3 times. This stop criterion of EMD can reduce the computational cost and achieve good performance of removing uneven lighting. It was shown in [2] that the last IMF may also be seen as a trend under certain conditions, though it is slightly oscillatory. The readers may wonder that why we don’t take the IMFs as our background level. The reason is that it may also be seen as a trend, but its total pixels’ mean value approximate zero. And the purpose of our method is to remove the uneven luminance, so we must use residue as the background level. In removing the uneven light distribution, the text image is firstly decomposed by EMD on rows and columns. The operation of performing EMD on rows and columns of images was first used in [5], interested readers may refer to it for more information. We take the average of the row residue and column residue as the approximate light distribution. For example, the approximate light distribution for Figure 1 is shown in Figure 2. Then, we can get the modified text document by the following equations.

\[
\text{Gain}(x, y) = I(x, y)/r_L(x, y)
\]

\[
I'(x, y) = \text{Gain}(x, y) \times 255
\]

where \( I(x, y) \) is the original pixel value, \( r_L(x, y) \) is the approximate light distribution pixel value and \( I(x, y) \) is the modified pixel value. The purpose of equation (2) is to get the contrast of image [6] [7] [8], and we modified it as equation (3) shows to change the light source in background to white light. The enhanced result is shown in Figure 3 (a). However, it is still not clear enough to be readable, so we modify the equation (2) again to the following equation to enhance the text information.
where $\alpha$ is the black control. The value of $\alpha$ is determined by the user to control the text content clarity. We can make the text blacker by setting the bigger value of $\alpha$ due to text image is usually black-and-white. Figure 3 (b) shows the results of $\alpha=2$. The processing flow diagram is summarized in Figure 4.

### 4. EXPERIMENTAL RESULTS

In order to demonstrate the performance of our algorithm, we take several text images with light source in different side by digital camera and transform them into grayscale images shown in the left column of Figure 5. These images are processed by our uneven lighting removal algorithm. Since EMD is adaptive locally according to image data, the proposed work can automatically compute the ratio of text to background level by equation (2) and use equation (3) to adjust background level to white. The results in Figure 3 and Figure 5, where the number of iterations in one sifting process is 5, the number of sifting process is 3 for each line-based EMD, and $\alpha=2$ in our experiment. These experimental results show that our algorithm can remove the non-uniform light distribution effectively no matter where the illuminant light is and turn the background of text images to white. Even when the text is not arranged horizontally, but is tilted by some angle, e.g.45-degree, as the last row of Figure 5 shows. The proposed method still works well and demonstrates its robustness. When the image is influenced by poor lighting and uneven lighting simultaneously, our approach still perform well. Recently, Angelica et al. [9] proposed a method using morphological background detection for enhancement of images with poor lighting. They demonstrated the superiority of their method in dealing with images with poor lighting. However, when the poorly lighted images are also suffered from uneven lighting, their method usually fails to tackle with it. As Figure 6 (b) shows, although the poorly lighted part at the right side of the image is enhanced, the well lighted left side is overenhanced. The histogram equalization method fails to deal with the test image well as Figure 6 (c) demonstrated. The resulted image in Figure 6 (d) by applying our method shows that the uneven lighting is removed and the scene is relighted naturally. Our method eliminates the uneven lighting successfully and demonstrates the text parts clearly, while the other two methods yield inferior results. These figures shows that our approach not only can deal with uneven lighting but also can perform well under the poor lighting condition or when the above factors are combined together. The images are enhanced more naturally and visually pleasing by our method, demonstrating the robustness and superiority of our approach under different lighting conditions in natural environments.

### 5. CONCLUSION

In this paper, a novel algorithm for image uneven lighting removal is proposed based on EMD. Besides, we give a new form of method using line-based EMD to decompose text images. The experimental results demonstrate that the proposed technique can effectively improve the light distribution for text images. This technique is valuable to improve the quality of image with poor light distribution.

### REFERENCES

Figure 5 Left column: text images with uneven lighting. Right column: uneven lighting removal with our algorithm.

Figure 6 (a) Image influenced by poor lighting and uneven lighting. (b) Enhance (a) by using [9]. (c) Enhance (a) by using histogram equalization. (d) Enhance (a) by using our approach.

