Adaptive Image Thresholding by Background Subtraction

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Abstract

In this paper, an adaptive image thresholding algorithm is proposed for thresholding images with uneven illumination. Firstly, a Gaussian scale space, which is produced from the convolution of a two-dimensional Gaussian function with an input image, is used to estimate the background image. Followed by background subtraction, the objective image can be easily obtained to eliminate interference of uneven illumination. Thirdly, to highlight those darker objects, gamma correction is employed to enhance the objective image. Finally, the thresholding result is extracted easily using the global valley-emphasis Otsu method. The experimental results show that the introduced method yields satisfactory visual quality.

Keywords: thresholding; background estimation; background subtraction

1 . Introduction

Image segmentation technique is a significant and challenge task in the field of image analysis, computer vision and pattern recognition, and also the basis of image understanding and object recognition [1-11]. Thresholding technique is one of the most popular image segmentation for its simplicity, efficiency and easy of understanding [2-11].

In this paper, an adaptive image thresholding algorithm by background subtraction is proposed for thresholding images with uneven illumination. Firstly, a Gaussian scale space, which is produced from the convolution of a two-dimensional Gaussian function with an input image, is used to estimate the background image. Followed by background subtraction, the objective image can be easily obtained to eliminate interference of uneven illumination. Thirdly, to highlight those darker objects, gamma correction is employed to enhance the objective image. Finally, the thresholding result is extracted easily using the global valley-emphasis Otsu method [7]. And the experimental results show that the introduced method yields better visual quality and lower misclassification error values than MFCM method [5] and GWT method [6].

2. Proposed algorithm

Our algorithm constructs a Gaussian scale space firstly computed as

$$f(x,y,\sigma)=G(x,y,\sigma)*I(x,y) \quad (1)$$

where σ denotes scale factor and $*$ denotes convolution operator. The average difference between two adjacent images is denoted by δ_i and calculated as

$$\delta_i=\frac{1}{M\times N}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}\left|f_{i+1}(x,y,\sigma_{i+1})-f_i(x,y,\sigma_i)\right| \quad (2)$$

where the size of the image is $M\times N$. Suppose intensity of background is low and intensity of foreground high. We can stop the iteration in terms of the change of the difference when constraint $\delta_i \le a$ is satisfied, where a is given error threshold.

According to the analysis above, the image $f_i(x,y,\sigma_i)$ can be regarded the i-th layer in the scale space as the estimated background. And then we can remove the uneven background illumination and obtain the object image:

$$D_i(x,y)=\left|I(x,y)-f_i(x,y,\sigma_i)\right| \quad (3)$$

For obtaining a very accurate object image and preserving much more object information, the final object image is calculated by a weighted summation of all the object images:

$$D(x,y)=\frac{1}{n}\sum_{i=0}^{n-1}D_i(x,y) \quad (4)$$

The intensities of foreground pixels in the object image is usually very dark after the elimination of uneven background illumination. For addressing this problem we apply γ operation to enhance the object image.

The enhanced image is hardly affected by the non-uniform illumination. Thus the global thresholding algorithm can be easily applied to it. Let the gray level is ranging from 0 to L-1. The number of pixels at level i is denoted by n_i. The total number of all pixels is denoted by n and $n=M\times N$. The probability of occurrence of level i is defined as $p_i=n_i/n$ and $\sum_{i=0}^{L-1}p_i=1$. Given a threshold t the image is divided into foreground C_0 and background C_1. Ng proposed an automatic thresholding algorithm and the objective function was defined as:

$$O(t)=(1-p_t)\cdot\left\{\frac{[\mu(t)]^2}{\omega(t)}+\frac{[\mu_T-\mu(t)]^2}{1-\omega(t)}\right\} \quad (5)$$

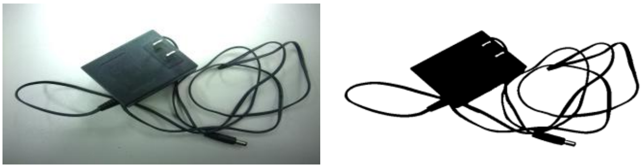
where $\omega(t)=\sum_{i=0}^{t}p_i$, $\mu(t)=\sum_{i=0}^{t}i\cdot p_i$ and $\mu_T=\sum_{i=0}^{L-1}i\cdot p_i$.

3. Results and Evaluation

Our experiment is implemented on a PC with AMD Athlon 7750 Dual-Core 2.70GHz CPU, 2G memory, VS2008 programming environment, using the C++ programming language.

Fig.1 shows the two testing images Text and Charger and their ground truth. Fig.2 displays the thresholding results of our method, grayscale wave transformation (GWT) method and MFCM method. The first row is the enhanced object image after the elimination of uneven background illumination. The 2-4 rows are thresholding results of our method, GWT method and MFCM method respectively. Note that the enhanced object image is very similar to the optimal binary image and helps for thresholding of our algorithm. Compared with GWT algorithm and MFCM algorithm, our algorithm provides very accurate thresholding results. From the segmentation results we can clearly find that there are much misclassification for the GWT method and the MFCM method.

(a) Text (b) Mask of Text



(c) Charger (d) Mask of Charger

Fig.1 Testing images and ground truth

(a) Enhanced ojbect image

(b) Our method

(c) GWT method

(d) MFCM method

Fig.2 Thresholding results

4. Conclusion

For thresholding images with uneven illumination we propose an adaptive image thresholding algorithm combined the background estimation in Gaussian scale space with the background subtraction. Our method firstly construct a Gaussian scale space using two-dimensional Gaussian function and estimate the background image of the input image need to be thresholded. And then we extract the difference as the object image using background subtraction scheme. Finally for obtaining a very accurate object image we enhance it using γ correction approach and the global thresholding algorithm is applied to the enhanced object image simultaneously. Our algorithm is more efficient for those uneven illumination images than GWT algorithm and MFCM algorithm.

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