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Image Binarization using Intensity Range of Grayscale Images

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Abstract

The performance of binarization algorithms is determined by the selection of threshold value for binarization, and most of the previous binarization algorithms analyze the intensity distribution of the original images by using the histogram and determine the threshold value using the mean value of intensity or the intensity value corresponding to the valley of the histogram. The previous algorithms could not get the proper threshold value in the case that doesn't show the bimodal characteristic in the intensity histogram or for the case that tries to separate the feature area from the original image. Therefore, this paper proposed a novel algorithm for image binarization, which, first segments the intensity range of grayscale images to several intervals and calculates a mean value of intensity for each interval, and then repeats the interval integration until getting the final threshold value. The interval integration of two neighborhood intervals calculates the ratio of the distances between mean value and adjacent boundary value of two intervals and determine as the threshold value of the new integrated interval the intensity value that divides the distance between mean values of two intervals according to the ratio. The experiment for performance evaluation showed that the proposed algorithm generates the more effective threshold value than the previous algorithms.

Keywords: *Binarization, thresholding, grayscale image, image processing*

1. Introduction

Binary image is the simple B/W image that is transformed from an original image for recognition and segmentation while maximally keeping original image information such as shapes and positions [1]. In the image processing, image binarization is used as a general tool for image segmentation of discriminating objects from background in various applications such as automatic target tracking, object recognition, image compression, and image analysis. The selection of threshold value is the important performance-critical problem in image processing application with binary images [2- 3].

Therefore, this paper proposed a novel algorithm selecting the threshold value by using the interval segmenting and integrating process of the intensity distribution of image.

The intensity range of grayscale images is segmented into 2^n intervals and the mean values of intensity for each interval are calculated. n is the experientially determined parameter according to the intensity distribution of images. Two neighborhood intervals of 2^n intervals are integrated into the new intervals of 2^{n-1} intervals. Next, the interval integration of two neighborhood intervals calculates the ratio of the distances between mean value and adjacent boundary value of two intervals and determine as the threshold value of the new integrated interval the intensity value that divides the distance between mean values of two intervals according to the ratio. The interval integration repeats until getting the final threshold value. Lastly, the final threshold value is applied to the binarization of the original image.

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2. Related Studies

The studies on getting the optimal threshold value for image binarization have been performed long ago and are classified into global method and local method. The selection of threshold value method with histogram analysis is not enough to analyze shapes of real image because of analysis based on a numerical distribution density. To improve this problem, the selection method of threshold value based on shape information of object with previous binarization is proposed [5,-6]. This method referred bit-plane by pre-acquiring whole shape information of image.

The bit-plane is the binary image that is represented with same space resolution by decomposing the digital coded stored image with the bit-array of an identical weight value. N-bit grayscale image is decomposed into N binary image by bit slice operation. Therefore, the binarization method with bit-plane binaries the image by discriminating object regions with background regions through the high bit-plane, which includes many outlines of the original image for grasping the general distribution of objects and background in the original image [7]. But these kinds of binarization methods can't apply to the image, which has the small difference between brightness of background and that of objects [8]. Therefore, this paper proposed a novel algorithm for selecting the threshold value with the interval segmenting and integrating process of intensity distribution of image.

3. Enhanced Image Binarization with Intensity Information

3.1. Second-Order Headings

The 256 intensity values of grayscale images are segmented into 2^1-2^5 intensity intervals. If intensity information is uniformly distributed, 2^2 or 2^3 intervals make satisfactory results. But images with dark or bright intensity as a whole have one-sided intensity values on the histogram.

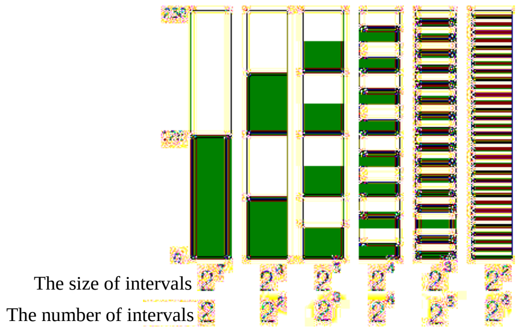


Figure 1. The Size of Intervals and the Number of Intervals

Therefore, generally the number of 2^4 or 2^5 intervals is more effective. Figure 1 shows the number and the size of intervals. If the number of intervals is increased, precise intensity distribution can be acquired. But the number of 2^6-2^7 intervals takes much processing time for determining the threshold value. The experiment showed the similar performance between 2^5 intervals and 2^6-2^7 ones. In this paper, the intensity interval is determined by Eq. (1).

$$\begin{aligned} & n = \log_2 R \\ & \lceil j \rceil = \frac{p_i}{2^{8-n}}, \; j = 1, 2, \ldots, 2^n \\ & X_j = X_j + P_i \end{aligned} \tag{1}$$

Here, R is the number of total intervals, P_i is the intensity value of pixel i, and X_j is the sum of intensity value of each intervals. The number of 2^n intervals is used because the final threshold value is acquired by repeating the interval integration process, which integrates two neighborhood intervals into the one new interval.

There are $2^{n\pm x}$ intervals until getting the final threshold value. The mean value of each intensity interval is calculated and is determined as the threshold value of the interval, and is identical to intensity distribution of corresponding intervals. In the case that shows the bimodal characteristic in the intensity histogram, the mean threshold value of intensity interval is located in the minimum of the valley. Otherwise, the mean threshold value of intensity interval is located in one sided intensity value position.

3.2 The Calculation of Final Threshold Value

First, two neighborhood intervals among 2^n intervals are integrated into new 2^{n-1} intervals. As an integrated interval includes two threshold values of the previous intervals, the paper calculates the ratio of the distances between mean value and the adjacent boundary value of two intervals and determine as the threshold value of the newly integrated interval the intensity value that divides the distance between mean values of two intervals according to the ratio. The interval integration repeats until getting the final threshold value. Lastly, the final threshold value is applied to the binarization of an original image. This process is represented in Figure 2 as a diagram and in Eq. (2) as a numerical formula.

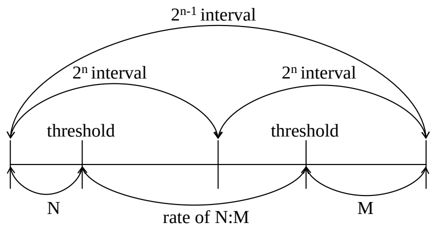


Figure 2. Image and the Determination of Threshold Value

$$T_i^{(n-1)} = T_{2i-1}^n + \frac{\left(T_{2i}^n - T_{2i-1}^n\right)T_{2i-1}^n}{T_{2i-1}^n + \left(2\left(2^n\right)\right)\times i - T_{2i}^n} \qquad (2)$$

$T_i^{(n-1)}$ means the i-th threshold value in 2^{n-1} integrated intervals. The interval integration and the calculation of threshold values of integrated intervals are repeated until getting the final threshold value of 2^0 intensity interval.

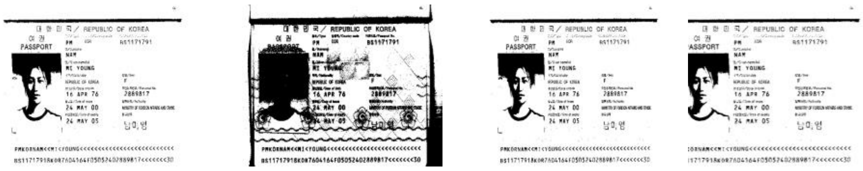
4. Experiments and Results Analysis

For the performance evaluation, the proposed method is implemented in Visual Studio 2008 C# with Intel® Core™ @ 3.40 GHz and 4 GB RAM PC. The images of passport (600×395), container (756×504), vertebral column (150×350), is applied to the experiment for comparing and evaluating the binarization performance of the proposed method and previous methods such as max-min average method, total average method, and most high bit of bit-plane method.

Figure 3 shows the image used in the experiment, and the number of intensity intervals of the proposed method is set up as 2^3. In the case of passport image, the discrimination of characters and picture is not clear because of the high threshold value of total average method. Other binarization methods don't make a big difference. Figure 4 shows binarized results of a passport image by each binarization method.

(a) Passport (b) Container (c) Vertebral Column

Figure 3. The Images in the Experiment



(a) Max-Min Average (b) Total Average (c) Bit-Plan (d) The Proposed Method

Figure 4. Binarization of Passport Image

Table 1 shows threshold values calculated by each method in the case of passport image. Figure 5 compares threshold values of the proposed method and the bit-plane method on the histogram.

Table 1. Threshold Values of Each Method in the Case of Passport Image

<table>
<tr><td rowspan="5">threshold value</td><td colspan="2">max-min</td><td colspan="2">total average</td><td>bit-plane</td></tr>
<tr><td colspan="2">150</td><td colspan="2">204</td><td>155</td></tr>
<tr><td colspan="5">The number of intervals of the proposed method</td></tr>
<tr><td>2^1</td><td>2^2</td><td>2^3</td><td>2^4</td><td>2^5</td></tr>
<tr><td>146.7</td><td>151.5</td><td>146,7</td><td>145.8</td><td>143.6</td></tr>
</table>

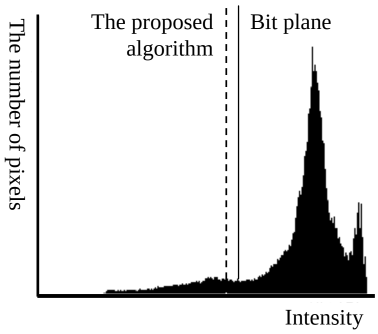


Figure 5. Histogram of Passport Image and Threshold Value

According to Table 1, in the case of 2^1 intensity intervals, the threshold value is differently set up with the expected threshold value because it does not reflect the intensity distribution. In the case of 2^2 to 2^5 intensity intervals, the threshold value is decreased.

The proposed method shows satisfactory results in the case of container image and vertebral column image, and can be applied to character recognition because of classifying the background of container identifiers into white color such as Figure 6. In the case of vertebral column image, as the numbers of intervals increases, the threshold value decreases.

(a) Max-Min Average (b) Total Average (c) Bit-Plan (d) The Proposed Method

Figure 6. Binarization of Container Image

(a) Max-Min Average (b) Total Average (c) Bit-Plan (d) The Proposed Method

Figure 7. Binarization of Vertebral Column Image

5. Conclusions

The image binarization is applied frequently as one part of the preprocessing phase for a variety of image processing techniques, such as character recognition and image analysis, *etc.* The performance of binarization algorithms is determined by the election of threshold value for binarization, and most of the previous binarization algorithms analyze the intensity distribution of the original images by using the histogram and determining the threshold value, using the mean value of intensity or the intensity value corresponding to the valley of the histogram. The previous algorithms could not get the proper threshold value in the case that it doesn't show the bimodal characteristic in the intensity histogram or for the case that tries to separate the feature area from the original image.

This paper proposed a novel algorithm for image binarization, which first segments the intensity range of a grayscale image to several intervals and calculates mean value of intensity for each interval, and then repeats the interval integration until getting the final threshold value. The interval integration of two neighborhood intervals calculates the ratio of the distances between mean value and the adjacent boundary value of two intervals and determines as the threshold value of the new integrated interval the intensity value that divides the distance between mean values of two intervals according to the ratio.

The next research topics are the setting-up method for the optimal numbers of intervals and the method for determining the threshold value between each interval.

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