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An Adaptive Threshold Method for Gray Scale Character Images

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Abstract

Gray-scale document images are binarized in order to perform optical character recognition (OCR). To perform this binarization, a variety of techniques have been proposed for performing threshold selection. Most of these are based on the intensity distribution of the image regions. However, when the spacing between two lines is very small, it is difficult to produce high quality characters using a fixed threshold. Also, with a fixed threshold, it is very hard to produce continuous lines when binarized, because the binarization introduces gaps within the line. This paper presents an adaptive threshold method based on gradient properties which handles the above problems. Our method consists of three steps. First we extract the pixels located at the boundary of a character and the background, then determine a threshold for each of the extracted pixels. After binarizing the boundary pixels, the remaining pixels are binarized based on the binarized boundary pixels. Our results show that an adaptive threshold produces higher quality binarized images than does the discriminant analysis method.

1 Introduction

Traditionally, optical character recognition (OC R) is performed on binarized images obtained from scanned gray-scale images. There have been many techniques proposed for binarizing these images [1] [2] [3] [4] [5], amongst these algorithms, the discriminant analysis [4] method is frequently used. This method utilizes statistical properties of the intensity histogram to determine a suitable threshold. While this method requires little computation, for document processing it tends to blur the character and introduces gaps among its lines, resulting in poor quality character images. Since it is difficult to perform recognition on these characters, it is important to develop a binarization technique which introduces fewer distortions during the binarization process. To date, there has been very little attention given to the binarization of individual characters.

Nakao et al.[6] introduced one technique for binarizing individual characters utilizing a different threshold for each character. In this technique, the full image is binarized, then the individual character regions are extracted. Finally, each of the character regions is binarized from the original gray-scale image using a threshold determined by estimating the black pixel ratio of the character's font. This method is similar to the discriminant analysis method in that it uses the intensity histogram to determine the threshold. As a result, this method also suffers from the blurring of characters and introduction of gaps among the lines.

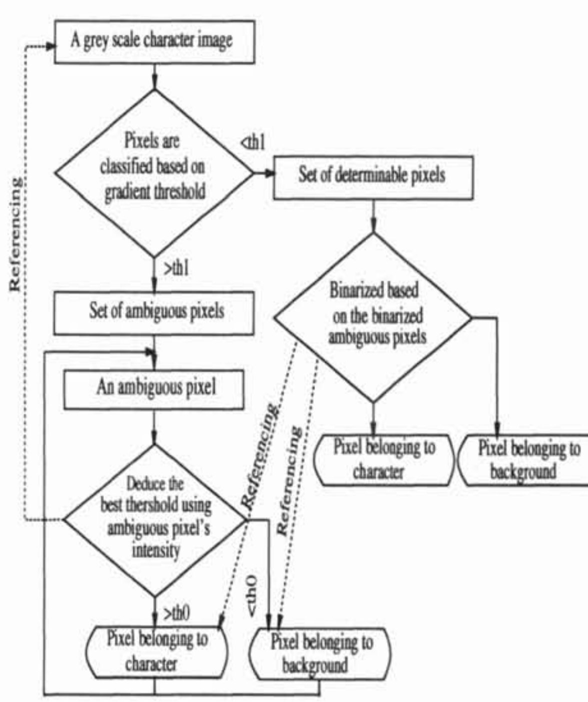

Figure 1: Binarization Processing Overview

To avoid the above mentioned binarization problems, we developed a binarization algorithm based on the gradient properties of the image. The intensity of an image's gradient is a very important property of the image. With it, the local pixel properties are clearly visible. Examining the gradients, the character boundaries stand out as sudden changes in the gradient intensities. In our algorithm, we use

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the gradient intensities to classify the character image's pixels into two categories: determinable and ambiguous. The boundary pixels are the ambiguous pixels, and the remainder are the determinable pixels. Each ambiguous pixel is binarized using an adaptive threshold. Finally, the determinable pixels are then binarized with expansion processing. By using this method, the blurring and gaps between lines are substantially reduced. An overview of the binarization process is shown in figure 1.

In section 2 we present the binarization process, show our experiment results in section 3, and then conclude.

2 Binarization Processing Methodology

Here we assume that the character regions have already been determined, and concentrate on the character binarization method. Binarization is a three step process.

(1) Based on the character's gradient properties, we determine the gradient threshold for maximizing the boundary region between the background and the character. The pixels in this boundary are the ambiguous pixels.

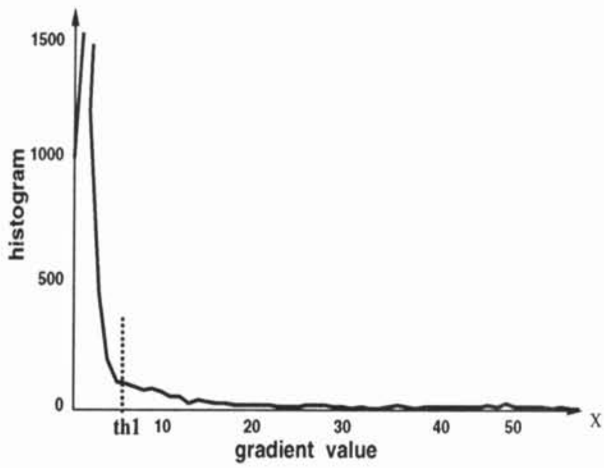
(2) For binarizing the ambiguous pixels, deduce an adaptive threshold from the intensities of the ambiguous pixels.

(3) Binarize the determinable pixels (non-boundary pixels) by expanding the binarized ambiguous pixels.

2.1 Classifying ambiguous pixels and determinable pixels

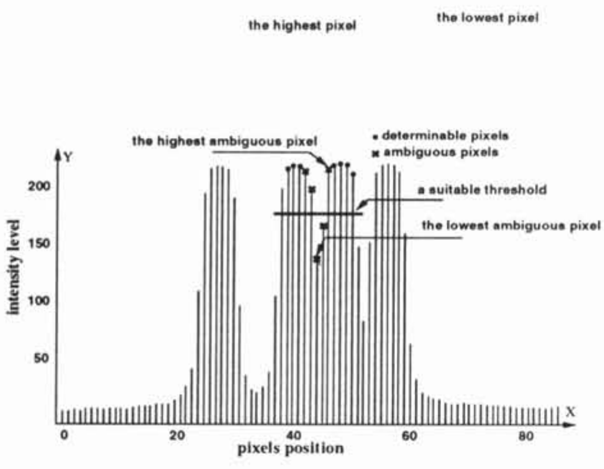
Figure 2b shows a character image gradient histogram. As can be seen from this figure, the frequency of occurrence of gradient values quickly drops and after the initial drop the rate of decrease is relatively small. The most appropriate threshold is the point where the rate of decrease in the occurrence frequency begins to level out. This threshold is called the gradient threshold (th1). Pixels whose gradient value are greater than th1 are the ambiguous pixels, while those no more than th1 are the determinable pixels. The reason that the location of the gradient threshold is most appropriate is that it increases the number of ambiguous pixels, thus making the task of finding a suitable adaptive threshold easier. The black regions in figure 2c show the ambiguous pixels as determined by the computed gradient threshold shown in figure 2b.

(a) A gray scale character image
(The line is y=35)



(b) Gradient histogram of the image

(c)Extraction of ambiguous pixels with th1
(black pixels)



(d) An intensity profile at y=35

Figure 2: An intensity profile and gradient histogram

2.2 An Adaptive Threshold Selection Method For Ambiguous Pixels

It is known that ambiguous pixels exist near image boundary regions, such as at the boundaries of the lines making up a character. With a fixed threshold, when the spacing between two lines is small, the lines often become merged, also fine lines often get broken into multiple segments. Using a different threshold for each ambiguous pixel helps to eliminate these problems. In order to distinguish the background from the character pixels, we determine a suitable threshold for each ambiguous pixel.

The ambiguous pixel's gradient vector is calculated using the Sobel operator using the original gray scale image. This gradient vector determines the scan direction. The possible gradient vectors are shown in figure 3, and figure 2d shows the intensity profile for figure 2a along the y=35 line (direction 1). The image is scanned to find other ambiguous pixels with the same gradient vector until a determinable pixel is encountered. The set of ambiguous pixels found is called the related ambiguous pixels. Finally, the intensity of the related ambiguous pixels is examined, and the average of the highest and lowest intensities is a suitable threshold for binarizing the related ambiguous pixels. This process is repeated for each ambiguous pixel.

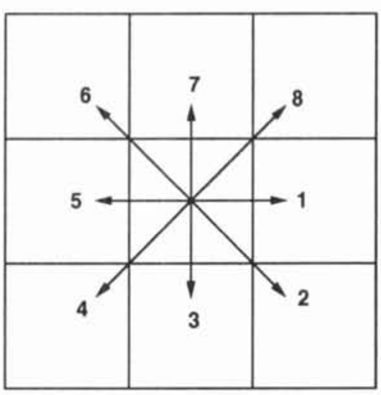


Figure 3: Gradient Direction Code

2.3 Processing Determinable Pixels

After binarizing the set of ambiguous pixels, we need to expand the pixels belonging to the character and background. We do this by examining the 8 neighboring pixels for each determinable pixel, and determining whether the pixel belongs to the character or background pixels.

3 Experiment Results

Figure 4 shows a character image for each step of the binarization process.

(a) (b) (c) (d)

Figure 4: A character image at various stages of processing.

(a) Original gray scale image
(b) Extraction of ambiguous pixels (black pixels)
(c) Ambiguous pixels binarized
(d) Determinable pixels binarized.

In order to evaluate our method, we chose images from the JIS (Japanese Industrial Standard) Kanji character set and compared the resulting images with those of the discriminant analysis method.

5(a) Discriminant analysis method

5(b) Our adaptive thresholding method

Figure 5: The resulting images for the 2 methods

The discriminant analysis method is based on the statistical properties of the intensity histogram. The bold Gothic font and Mintyou font are easily blurred when they are binarized with this method, As can be seen in figure 5a, the discriminant analysis method is unable to detect the background between lines which are closely spaced, producing a poor binarized image in this case because it only uses the properties of the intensity histogram and uses a fixed threshold value.

However, as can be seen in figure 5b, our algorithm is effective in detecting the background among the lines through the use of an adaptive threshold for each ambiguous pixel, improving the image quality of the binarized image.

On the other hand, binarizing characters from the Gothic and Mintyou fine fonts results in gaps within the character's lines. Figure 6a shows a group of Mintyou fine characters which because of their low intensity tend to have some of the character pixels converted into background ones by the discriminant analysis method. Our algorithm is able to avoid the breaking of fine lines into multiple segments as shown in figure 5b.

These results show that our algorithm is able to deal with the two problems which occur during binarization with the discriminant analysis method and results in better image quality.

6(a) Discriminant analysis method

6(b) Our adaptive thresholding method

Figure 6: The resulting images for the 2 methods

4 Conclusion

Due to the difficulty of improving document image quality using a fixed threshold and just the intensity histogram, we have presented an adaptive thresholding method for binarizing document images based on gradient properties. The method includes extracting the ambiguous pixels, deducing a suitable threshold for each ambiguous pixel, and binarizing the determinable pixels using expansion. Experimental results show that the algorithm is able to avoid the blurring of lines separated by a small space, and also avoids introducing gaps within the character's lines.

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