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Gabor filters-based feature extraction for character recognition

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Abstract

A new method using Gabor filters for character recognition in gray-scale images is proposed in this paper. Features are extracted directly from gray-scale character images by Gabor filters which are specially designed from statistical information of character structures. An adaptive sigmoid function is applied to the outputs of Gabor filters to achieve better performance on low-quality images. In order to enhance the discriminability of the extracted features, the positive and the negative real parts of the outputs from the Gabor filters are used separately to construct histogram features. Experiments show us that the proposed method has excellent performance on both low-quality machine-printed character recognition and cursive handwritten character recognition.

Keywords: Character recognition; Gabor filters

1. Introduction

In the field of document image analysis and recognition, researchers have achieved great success in character recognition during the past decades [1]. However, there still exist two challenging problems. The first one is the optical character recognition (OCR) in low-quality images. Some difficulties are from the illumination variance, noise, complex and dirty background. In these cases it is extremely difficult for us to get clean binary character images from the gray-scale ones. This will result in low-recognition accuracy by traditional character recognition methods based on binarized character images. The second one is the cursive handwritten character recognition [2], especially for off-line cursive handwritten Chinese character recognition(OCHCCR) which is considered as one of the most difficult problems in the area of character recognition. The difficulties are from the following four aspects: (1) The Chinese character set is huge. In our daily life, we use about 3755 Chinese characters. (2) The complex structures of Chinese characters. Some Chinese characters have more than 20 strokes. (3) There are a lot of similar characters existing in this huge character set. Some similar characters can only be discriminated by just one stroke. (4) Handwriting individualities, i.e. different people have different handwriting styles. Therefore, we have focused a lot of efforts on OCHCCR in our research work. On the other hand, a lot of existing applications such as wafer OCR, vehicle license plate recognition, bank check image processing, postal address block detection and recognition, camera OCR, and so on, greatly depend on robust character recognition technology with high accuracy. This paper will introduce a new feature extraction method based on Gabor filters for robust character recognition.

As for the problem of OCR in low-quality images, two different approaches have been developed. The first one is

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to binarize the gray-scale image by choosing an appropriate threshold and then do the feature extraction on the binarized image [3–5]. However, the binarization process needs detailed information of image degradation to discriminate the character stroke pixels from the background pixels. For low-quality images, it is almost impossible to get such an accurate degradation model. So the binarization process will inevitably result in information loss and will generate a lot of broken strokes or connected strokes and noise into the binarized image. The other approach, on the other hand, works directly on gray-scale images without binarization [6,7]. Obviously, it avoids the above disadvantages from the binarization step. This approach includes the following categories: (1) topographical feature extraction or edge detection directly from gray-scale images [7]; (2) global feature extraction by discrete cosine transform (DCT) or moment transform [6]; (3) image registration [8]. These methods can obtain some improvements in some cases such as blur character recognition but work poorly in other cases. For example, topographical features have poor performance on images with noise or dirty background. Methods such as DCT, moment transform and image registration are very sensitive to illumination variance and character distortion. The new feature extraction method based on Gabor filters proposed in this paper tries to solve this difficult problem.

As for the second challenging problem, i.e. the off-line handwritten Chinese character recognition, researchers have got great success by applying directional element features (DEF) and modified quadratic discriminant function (MQDF) classifiers [9]. The popular classifier combination [10] and minimum classification error (MCE) training [11] have also been used to solve this problem and have somewhat improved the recognition accuracy. However, newly developed methods such as support vector machines (SVM) [12,13] and tangent distance classifier [14] cannot be easily used for this difficult problem because of the large Chinese character set and complicated structures of Chinese characters. The Gabor filter-based feature extraction method proposed in this paper tries to further improve the recognition performance not only in low-quality images but also for off-line handwritten Chinese characters. It extracts local features directly from the gray-scale images so as to avoid the information loss by the binarization step and to tolerate the stroke variation and character distortion from different handwriting styles. This method applies multi-directional Gabor filters to the extraction of stroke information which builds the basic structures of characters. In this method, the advantages of image analysis based on both spatial domain and frequency domain is well-combined and robust local features are easily extracted which are powerful in discriminating different character strokes from noisy background.

Moreover, an adaptive regulation method is applied to the outputs of Gabor filters so as to get better performance for low-quality images. In our further research, experiments show that the discriminability of histogram features can be greatly improved by separately counting the positive and negative real parts of the Gabor filter outputs. These efforts have achieved significant improvement and are proved to be very effective for both OCR in low-quality images and off-line handwritten Chinese character recognition.

This paper is organized as follows. In Section 2, we will give a brief description of Gabor filters and related research work on Gabor filters. In Section 3, the statistical properties of local structures of Chinese characters will be described, which will be helpful in developing a simple but effective Gabor filter design algorithm. The details of the proposed Gabor filter-based feature extraction method for robust character recognition will be given in Section 4. In Section 4.3, experimental results on both OCR in low-quality images and off-line handwritten character recognition will be given in detail. These results will also demonstrate that the proposed method is powerful and effective in solving the two challenging problems mentioned above.

2. Theory of Gabor filters

Gabor filters have been used extensively in image processing, texture analysis for their excellent properties: optimal joint spatial\spatial-frequency localization and ability to simulate the receptive fields of simple cells in the visual cortex [15–17]. Two-dimensional Gabor filter is a complex sinusoidally modulated Gaussian function with the response in spatial domain (Eq. (1)) and in spatial-frequency domain (Eq. (2)) as follows (Fig. 1):

$$h(x, y; \lambda, \phi, \sigma_x, \sigma_y) = \frac{1}{2\pi\sigma_x\sigma_y} \exp\left\{-\frac{1}{2}\left[\frac{R_1^2}{\sigma_x^2} + \frac{R_2^2}{\sigma_y^2}\right]\right\} \times \exp\left[\mathrm{i} \cdot \frac{2\pi R_1}{\lambda}\right], \tag{1}$$

where

$$R_1 = x\cos\phi + y\sin\phi,$$
$$R_2 = -x\sin\phi + y\cos\phi.$$

$$H(u, v; \lambda, \phi, \sigma_x, \sigma_y) = C\exp\left\{-2\pi^2\left(\sigma_x^2\left(F_1 - \frac{1}{\lambda}\right)^2 + \sigma_y^2 (F_2)^2\right)\right\}, \tag{2}$$

where

$$\begin{array}{l} F_1 = u\cos\phi + v\sin\phi \\ F_2 = -u\sin\phi + v\cos\phi \end{array}, \quad C = const.$$

Spatial localization of Gabor filter can be depicted by Δx and Δy which are standard measures of effective spatial widths [15]

$$(\Delta x)^2 = \frac{\int_{-\infty}^{+\infty} h\,h^* (R_1)^2\,\mathrm{d}(R_1)}{\int_{-\infty}^{+\infty} h\,h^*\,\mathrm{d}(R_1)},$$
$$(\Delta y)^2 = \frac{\int_{-\infty}^{+\infty} h\,h^* (R_2)^2\,\mathrm{d}(R_2)}{\int_{-\infty}^{+\infty} h\,h^*\,\mathrm{d}(R_2)} \tag{3}$$