Structure Extraction from Various Kinds of Decorated Characters Using Multi-Scale Images

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Abstract

Decorated characters are widely used in various documents. Practical optical character reader is required to deal with not only common fonts but also complex designed fonts. However, since appearances of decorated characters are complicated, most general character recognition systems cannot give good performances on decorated characters. In this paper, an algorithm that can extract character's essential structure from a decorated character is proposed. This algorithm is applied in preprocessing of character recognition. The proposed algorithm consists of three parts: global structure extraction, interpolation of structure, and smoothing. By using multi-scale images, topographical features such as ridges and ravines are detected for structure extraction. Ridges are used for extracting global structure, and ravines are used for interpolation. Experimental results show clear character structures are extracted from very complex decorated characters.

1. Introduction

Decorated characters are widely used in various documents. Practical optical character reader (OCR) is required to deal with not only common fonts but also complex designed fonts.

A lot of approaches of character recognition have been developed [5, 8]. The approaches can be classified into two categories: structural analysis and pattern matching. In both categories, features of character images are extracted based on the information of connected components of black pixels. However, appearances of decorated characters are so complicated and strange that there is no guarantee that the connected components of black pixels represent the essential structure of the character. Moreover, it is difficult to construct standard patterns for decorated characters, since there are various kinds of fonts that are specially designed. Therefore, most general character recognition systems cannot give good performances on decorated characters.

Some special methods that deal with decorated characters used in headlines are proposed [6, 9, 10]. However, all of these methods only cope with special case that characters represented by texture images or characters with textured background. Broken or degraded character recognition [1, 3] sometimes requires the same kinds of techniques as the recognition of decorated characters since the broken or degraded parts of a character may be regarded as decorations. However, obviously decorated character recognition is much more difficult and complex.

Usually, decorated characters are constructed by one or combination of the following four procedures: (1) using texture images, (2) transforming the structure of the original character, (3) adding some decorations, (4) deleting some parts of a character. Therefore, it is necessary for character structure extraction to erase the texture, to delete the additional decoration, and to interpolate the deleted parts.

By investigating the peculiarities of decorated characters, in this paper, an algorithm that can extract character's essential structure from a decorated character is proposed. This algorithm is applied in preprocessing of character recognition. The algorithm consists of three parts: global structure extraction, interpolation of structure, and smoothing. In the proposed algorithm, topographical features such as ridges and ravines obtained from *intensity surface* [2, 4] are extracted from multi-scale images. Ridges are used for global structure extraction, and ravines are used for interpolation. Experimental results show clear character structures are extracted from very complex decorated characters. Moreover, the effectiveness of the algorithm is shown by recognition experiments with decorated characters.

(a) Logotype. (b) Character A.

Figure 1. Examples of decorated characters.

2. Structure extraction from decorated characters

2.1. Structure of decorated characters

Fig. 1 gives some kinds of decorated characters. In the figure, (a) shows a logotype, and (b) shows four different fonts of character A. These A's are some examples of decorated characters discussed in [11]. Investigating these characters, it is easy to know that global structures represent the outward forms of the characters, while local structures are decorations. The characters' essential structures can be obtained by extracting the global structure.

One possible method for extracting global structure of an image is blurring and binarization. However, appropriate degree of blur and threshold of binarization depend on individual decorated character. Moreover, blurring will change the character structure in unexpected way in some cases. Therefore, it is difficult to extract character structure from decorated character using simple blurring technique without human operations.

In the proposed algorithm, images are blurred with various values of parameter to get multi-scale images. Furthermore, from the multi-scale images, the necessary information of topographical features for extracting global and local character structures are obtained.

2.2. Multi-scale images

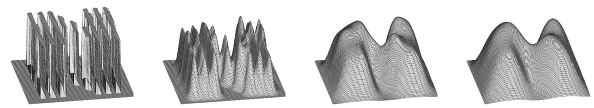
In the proposed algorithm, the intensity surfaces of multi-scale images are used to extract the character's structure. If an image is blurred by Gaussian filter, brightness of each pixel is changed according to *scale*. Here, scale means the variance of the Gaussian filter. Scale-space describes the information of the thickness of each part of an image at each scale [7]. Scale-space $L(x, y; t)$ of an image $f(x, y)$ is the convolution of $f(x, y)$ and Gaussian function $g(x, y; t)$ with scale t, and it is given by the following function.

$$L(x, y; t) = g(x, y; t) * f(x, y). \qquad (1)$$

By blurring the original image at various scales, multi-scale images are obtained. Multi-scale images of character N in Fig. 1(a) are displayed in Fig. 2. In this figure, (a) is the original image, and (b)∼(d) are the images that are blurred at various scales. Fig. 3 shows the intensity surface of each case in Fig. 2. Global and local structure are extracted based on these intensity surfaces of the multi-scale images.

(a) $t = 0$ (b) $t = 10$ (c) $t = 50$ (d) $t = 100$

Figure 2. Multi-scale images.



(a) $t = 0$ (b) $t = 10$ (c) $t = 50$ (d) $t = 100$

Figure 3. Intensity surfaces.

2.3. Global structure extraction

Using the intensity surfaces, a method of extracting global structure by detecting ridges is proposed. By observing Fig. 3, it is thought if the ridges of the intensity surface of image blurred at a certain scale represent the global structure, the global structure can be extracted by detecting ridges at that scale. For each pixel of the image, denote the direction that the absolute value of quadratic differential is maximum as p, and its orthogonal direction as q. The condition that (x, y) is a pixel on the ridge at scale t is,

$$\frac{\partial L(x, y; t)}{\partial p} = 0, \quad \frac{\partial^2 L(x, y; t)}{\partial p^2} < 0. \qquad (2)$$

For simplicity, p and q are quantized to one of the eight kinds of directions ($45^\circ \times n, 0 \leq n \leq 7$).

For structure extraction, appropriate pixels that represent the structure of character need to be selected among the points that satisfy Eq. (2). In this paper, ridge strength is defined as Eq. (3) and the ridge pixels are selected by choosing the scale t at which the strength is the local maximum.

$$S(x, y; t) = \left\{ \frac{\partial^2 L(x, y; t)}{\partial p^2} - \frac{\partial^2 L(x, y; t)}{\partial q^2} \right\}^2. \qquad (3)$$

If the following conditions are satisfied, the ridge strength will be the local maximum at (x, y).

$$\frac{\partial S(x, y; t)}{\partial t} = 0, \quad \frac{\partial^2 S(x, y; t)}{\partial t^2} < 0. \qquad (4)$$

However, if the above processing is applied directly to decorated character images, local structures are extracted simultaneously, and it makes the essential structure extraction impossible. An example of this problem is shown in

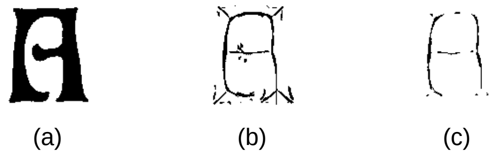


Figure 4. Ridge detection. (a) Original image. (b) All the ridges are detected. (c) Only strong ridges are extracted.

Fig. 4. Fig. 4(a) is the original image, and Fig.4(b) shows all the black pixels of Fig. 4(a) that satisfy Eqs. (2) and (4). Fig.4(b) shows that although the global structure of character A is extracted, the local structures of decorations are also extracted simultaneously. It is obviously that how to avoid extracting local structures is a big problem. Here, to choose the ridges that represent the global structure, the pixels with large value of ridge strength (Eq. (3)) are used.

Global structure extraction processing is summarized as follows. First, multi-scale images are obtained by blurring the original image by changing the scale from $t = 1$ to $t = 100$. Then the pixels that satisfy Eqs. (2) and (4) are extracted. Denote the number of extracted pixels be N, and among these pixels, θN pixels whose ridge strength calculated by Eq. (3) are large are chosen. Here, θ is a constant that satisfies $0 < \theta \leq 1$.

Fig. 4(c) shows the result of extracting global structure from Fig. 4(a). Here, $\theta = 0.4$. This figure shows that the local structures are removed while the global structure of the original image is extracted successfully.

However, Fig. 4(c) is not a connected structure. To enable the recognition of the decorated character, it is necessary to extract the connected structure that represents the character's essential structure. In the next section, a method for acquisition of the connected structure by interpolating discontinuous line segments is presented.

2.4. Interpolation of structure by recursive ravine detection

For interpolation, a method of interpolating gaps between lines by detecting ravines recursively is proposed. The condition that (x, y) is a pixel on ravine at scale t is,

$$\frac{\partial L(x,y;t)}{\partial p} = 0, \quad \frac{\partial^2 L(x,y;t)}{\partial p^2} > 0. \tag{5}$$

If larger scale t is adopted, wider gap between lines can be interpolated. Interpolation algorithm by recursive ravine detection is as follows.

1. Initial value of scale t_1 is given. $t \leftarrow t_1$.
2. Detect ravines at scale t. Detected ravines are added to the image.

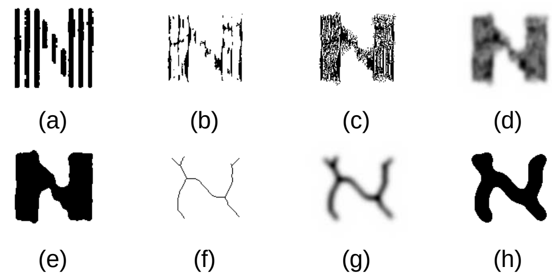


Figure 5. Structure extraction of a decorated character. (a) Original image. (b) Detected ridges. (c) Ravines are detected recursively and are added to the image of (b). (d) Blurred. (e) Binarized. (f) Skeletonized. (g) Blurred. (h) Result.

3. $t \leftarrow t/2$.
4. 2. and 3. are repeated for k times.
5. Blur the image at a small scale.

Here, $t_1 = 30$ and $k = 5$.

2.5. Smoothing by thinning

The line widths of images obtained by the method described in the previous sections are not uniform. Moreover there are unevenness on the contours since the decorated structures are partially left. In order to resolve these problems, smoothing is needed. Smoothing is done by thinning, blurring at a small scale, and binarization.

Fig. 5 displays the process of character structure extraction of decorated character N.

3. Experiments

In order to verify the effect of our method, the proposed algorithm is applied for character structure extraction. Furthermore, recognition experiments are carried out. Three different characters segmented from the logotype in Fig. 1(a) and four kinds of character A in Fig. 1(b) are used for evaluation. For recognition, an existing OCR is adopted. The original images and the results are shown in Table 1. In the table, the results below the original images are the results of recognizing the original images using the OCR, while the results below the extracted images are the recognition results of the extracted character structures by the same OCR.

Although totally different kinds of decorated character images are tested, the extracted images in Table 1 show that character structure is clearly obtained in every case. These

Table 1. Results of structure extraction and recognition.

	(a)	(b)	(c)	(d)	(e)	(f)	(g)
Original image							
Result	I ’,Jt		I Iljll’	j˜	˜	A	El
Extracted image							
Result	N	E	W	A	A	A	R

results clarify the effectiveness of the proposed algorithm. Original character images are recognized incorrectly except (f). For the cases of (a) and (c), texture images are regarded as a combination of many characters, since decorations are extracted as the important features of characters. Compared with these results, most of the images extracted by the proposed algorithm are correctly recognized. The only failed case is (g) that A is recognized as R. Since the topological features of A and R are similar, it is thought to be necessary to use the knowledge of natural languages for distinguishing them.

For comparison, experiments without ridge detection are also carried out. In this case, (a) and (g) are not recognized correctly. In addition, although (f) is recognized correctly, extracted image is far from that of character A.

4. Conclusions

Decorated characters are widely used in various documents. Practical OCR is required to cope with not only common fonts but also complex designed characters. In the case of recognizing decorated characters, the most important point is to separate character’s essential structures from decorated parts.

In this paper, an algorithm for extracting character structures from various kinds of decorated character images was proposed. This algorithm is applied in preprocessing of character recognition. The proposed algorithm consists of three parts: global structure extraction, interpolation of structure, and smoothing. First, global structure is obtained by detecting strong ridges using multi-scale images. Next, gaps are interpolated by recursive ravine detection. Finally, character structure that is appropriate for recognition is made by smoothing.

A logotype and several different designed characters of A were used to investigate the effectiveness of our algorithm. The results have shown that structures of decorated characters are extracted successfully. These clear structures make the recognition possible. The recognition results have proved that although the original decorated characters are unrecognizable, after applying our algorithm in the preprocessing, almost all the decorated characters can be recognized correctly.

Although the complex designed characters tested in this paper are almost recognized successfully, it dose not mean our method can deal with any kind of decorated character. In order to improve our method, much more kinds of decorated characters should be tested. Moreover, in this paper, optimal character recognition method has not been considered. Recognition method which is suitable for the images obtained by the proposed algorithm is needed to be developed. Applying the algorithm for decorated digits is also a future work.

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