Automatic Generation of Chinese Character Using Features Fusion from Calligraphy and Font

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ABSTRACT

A spatial statistic based contour feature representation is proposed to achieve extraction of local contour feature from Chinese calligraphy character, and a features fusion strategy is designed to automatically generate new hybrid character, making well use of contour feature of calligraphy and structural feature of font. The features fusion strategy employs dilation and erosion operations iteratively to inject the extracted contour feature from Chinese calligraphy into font, which are similar to "pad" and "cut" in a sculpture progress. Experimental results demonstrate that the generated new hybrid character hold both contour feature of calligraphy and structural feature of font. Especially, two kinds of Chinese calligraphy skills called "Fei Bai" and "Zhang Mo" are imitated in the hybrid character. "Fei Bai" depicts a phenomenon that part of a stroke fade out due to the fast movement of hair brush or the lack of ink, and "Zhang Mo" describes a condition that hair brush holds so much ink that strokes overlap.

Keywords: Chinese character, automatic generation, calligraphy, font, features fusion

1. INTRODUCTION

Chinese character deeply influences people's daily life in Southeast Asia, which is an indispensable tool to transmit information and manifest handwriting art. It is significant to explore glyph, which influences human cognition and vision, utilizing advanced modern digital algorithms. Recently, much research has been made on automatic imitation of Chinese calligraphy. However, few consider making well use of font to synthesize calligraphy. Deviating from previous work, an automatic generation strategy of Chinese character is proposed in this paper which yields new hybrid character, exploiting features fusion from artistic contour feature of calligraphy and elaborate structural feature of font.

According to generation mechanism, algorithms on automatic generation of Chinese character can be generally divided into two categories: strokes and radicals reused algorithm (SRRA)[1-4] and stroke order drawing algorithm (SODA)[5-10]. SODA imitates handwriting process depending on stroke order. In ancient China, hairy brush was the most popular and widespread writing tool. Naturally, through analyzing physical properties of Chinese hairy brush, Mi et al.[11, 12] build a virtual brush model which operates digital droplet to generate Chinese calligraphy. To get more vivid visual effect, Bai et al.[5, 8] explore geometric deformation of hairy brush under external force, and propose a geometry model and dynamic model for brush, achieving imitation of handwriting process and painting process. An inevitable problem on modeling hairy brush is high computational complexity. To reduce computational cost, Yao et al.[7] utilize mechanical parameter to adjust spline curves which compose calligraphy glyph. To improve visual acceptance of generated calligraphy, Xu et al.[13] employ a more robust parametric representation of drawing trajectories utilizing supervised machine learning algorithm. Similarly, Yang and Li[6] exploit prior knowledge and inherent geometric features of sample characters to parameterize strokes of Chinese characters. Adopting prior knowledge of Chinese calligraphy, Shi et al.[14] propose the criteria of visual aesthetics based on Marr's vision assumption for a novel algorithm of automatic generation of Chinese character.

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The other category of methodology to automatically generate Chinese character is SRRA, which arranges sample strokes and radicals to compose characters. The primary task of SRRA is to analyze the hierarchical relationships of components, including strokes and radicals. Through analysis, Lai et al.[2, 3] present a structural expression for Chinese character and glyph beauty metrics from traditional Chinese calligraphy, in order to automatically generate glyph. Considering more about contour feature of strokes as well as structural feature, Xu et al.[1, 4] develop an algorithm for automatic character generation depending on both stroke feature which presents local style and geometry topology indicating global structural feature of glyph. Shi et al.[15] propose an effectively algorithm to generate a new hybrid character type by means of integrating local contour feature of Chinese calligraphy. A great number of SODA and SRRA is presented to multiply Chinese handwriting, and it is hard to introduce all of them in this paper.

As mentioned above existing works, few takes features fusion into account using font and calligraphy. This paper proposes a novel strategy to generate Chinese character through features fusion from local contour feature of calligraphy and elaborate structural feature of font, as shown in Figure 1, which includes three main steps: Contour Extraction, Parameter Estimation, and Features Fusion. Section 2 introduces contour extraction and proposes parameter estimation methodology, to extract local contour feature from Chinese calligraphy character. A novel features fusion algorithm is presented in section 3, to generate hybrid Chinese character. The experimental results and discussion are in section 4. The conclusion is given in last section.

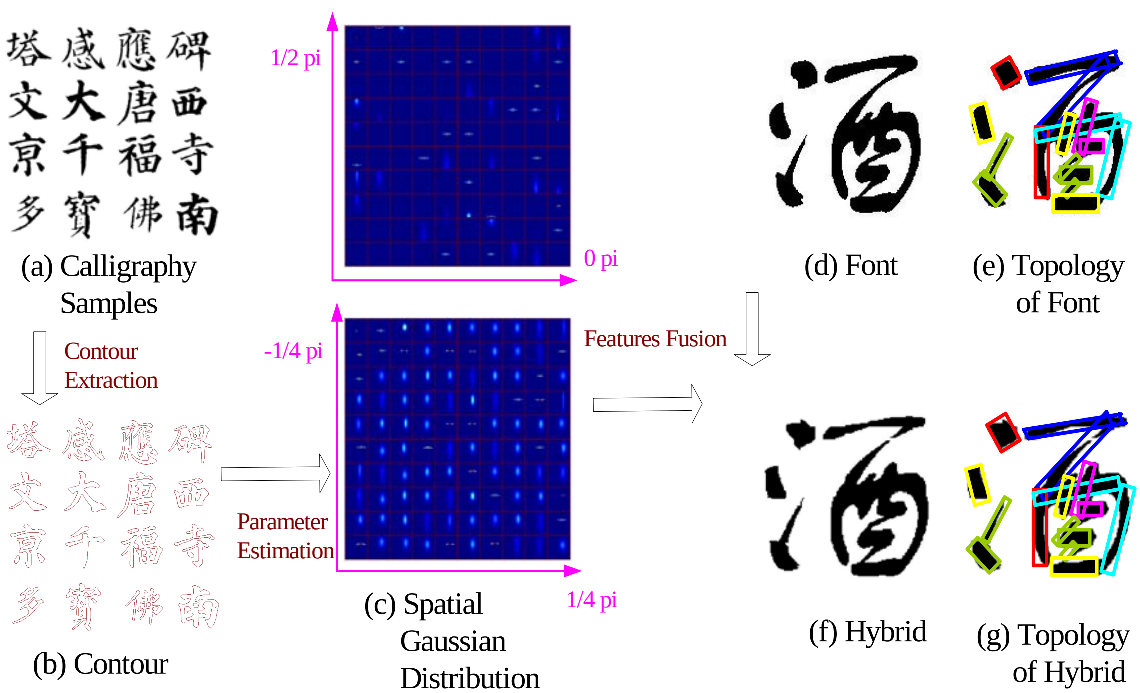

Figure 1: The proposed strategy to integrating local contour feature of calligraphy with structural feature of font.

2. PARAMETER ESTIMATION FOR SPATIAL GAUSSIAN DISTRIBUTION OF CALLIGRAPHY CONTOUR

The preliminary step to extract local contour feature of calligraphy is Contour Extraction illustrated in Figure 1. The contour (Figure 1(b)) is extracted from Chinese calligraphy character (Figure 1(a)) utilizing Canny edge detector. Each character contour image is divided into blocks, and then each block is filtered by a series of line detectors with one pixel width and various slopes. The probability distribution of responses of blocks, at particular position (x, y) in a set of calligraphy images, after spatial filtering using line detector with specific slope: $\tan(\theta)$, is estimated with Gaussian function. The distribution is used to represent local contour feature of calligraphy. Figure 1(c) visualizes Gaussian distributions at 10×10 positions with $\theta=\{1/4\,\pi, -1/4\,\pi, 0, 1/2\,\pi\}$ from the calligraphist Yan Zhenqing's character set. And the local contour is injected into font in Features Fusion step, which combines contour feature (Figure 1(c)) from calligraphy and structural feature from font (Figure 1(d)). Finally, hybrid of calligraphy and font is generated in Figure 1(f). As shown in Figure 1(e), the layout of bounding boxes illustrates topology of strokes. And Figure 1(g) almost shows the same topology corresponding to Figure 1(e). In other words, hybrid character (Figure 1(f)) gains local contour feature from calligraphy, as well as maintains structural feature from font.

After gaining responses of image blocks filtered by a series of line detectors, as described above, an *Area Threshold* and *Endpoint Detector* are exploited to refine responses for more exact parameters of Spatial Gaussian Distribution (Figure 1(c)):

- *Area Threshold*. Actually, the effective area of response of contour block image, after filtering with line detector, maybe too small, such as a dot. To solve this problem, an area threshold is applied to the response. Only the response with larger area than the area threshold is retained as output, otherwise others response is discarded.
- *Endpoint Detector*. Output of area threshold operation possibly have more than one line/curve or a cross line. To overcome multi-value and invalid value of slope, an endpoint detector is applied. If output of area threshold contains and only contains two endpoints, it is used to calculate slope.

Output of endpoint detection operation contributes to estimate parameters of Gaussian distribution:

$$G\left(slope\right)_{(x,y),\tan(\theta)}=\frac{1}{\left(2\pi\delta^{2}\right)^{1/2}}\exp\left\{-\frac{1}{2\delta^{2}}\left(slope-\mu\right)^{2}\right\} \tag{1}$$

which represents the specific slope ($\tan(\theta)$) distribution of character image block at particular position (x, y) in a calligraphy set. As a visualization for the result of the contour feature extraction, Figure 1(c) illustrates four specific slopes $\left(\theta=\{1/4\,\pi, -1/4\,\pi, 0, 1/2\,\pi\}\right)$ distribution at 10×10 positions considering the collected character set (Figure 1(a)).

3. FEATURES FUSION FROM CALLIGRAPHY AND FONT

The contour feature at (x, y) defined in (1) is injected into font image block at (x, y) in this section, so as to achieve features fusion from local contour feature of calligraphy and elaborate structural feature of font. To locate the accurate position (x, y), font image is divided into blocks as many as the number of image blocks from divided calligraphy character in section 2. And then the only one TBD parameter in (1) is θ. Font image block is also filtered by a series of line detectors, similar to line detectors used for calligraphy character in section 2. After endpoint detection operation and area threshold operation defined in section 2, the best θ with the maximum response is selected for (1). Finally, parameters μ and δ in (1) are determined. A slope can be generated according to:

$$slope'=\mu+k\delta \tag{2}$$

which is used to generate a line dilation operator with the slope: $slope'$, and k is a adjustable parameter. A variable-size cross erosion operator is defined as:

$$C_s = \begin{bmatrix} 0 & \cdots & 1 & \cdots & 0 \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ 1 & \cdots & 1 & \cdots & 1 \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ 0 & \cdots & 1 & \cdots & 0 \end{bmatrix}_{s \times s} \tag{3}$$

where s indicates the size of erosion operator C_s, and s must be an odd number. Only the middle vertical column and the middle horizontal row contain the number: "1", all the rest elements in C_s are "0".

The dilation operator and the erosion operator are iteratively executed to adjust boundary of font. The adjustment process can be seen as a sculpture process. The dilation injects local contour feature of calligraphy into font containing elaborate structure, using "pad", whereas, erosion acts as a "graver" to "cut" contour of font.

4. EXPERIMENT AND ANALYSIS

To evaluate the proposed integration framework, a famous ancient calligraphist Yan Zhenqing's 130 calligraphy characters was collected. The width and the height of character images range roughly between 110 and 160, and between 100 and 160 respectively (Units: Pixels). Figure 2 illustrates ten sample images. Experiments integrated calligraphy from the calligraphist with four fonts, which are designed according to handwriting. Two are "Li Shu" and "Wei Bei" imitating ancient brush calligraphy, and the other two are "Kai Ti" and "Shu Ti" emulating modern pen handwriting. And the setup is as follows: contour image of each calligraphy character is divided into 10×10 blocks, the size of the line detector in section 2 is 5×5, and $\theta = 0, \pi/2, \pi/4, -\pi/4$. The area threshold value is 5. The local contour feature for the calligraphist can be gained using formula (1). In the features fusion process, the image sizes of four fonts are 480×470, 490×330, 500×440 and 440×430 respectively. Each font image is also divided into 10×10 blocks, $\theta = 0, \pi/2, \pi/4, -\pi/4$ in section 3, and $k = 0$ in (2). The influence of the size of dilation operator in section 3 and the size of erosion operator in (3) were analyzed in the following experiments.

Figure 2: Ten sample characters written by a famous calligraphist Yan Zhenqing (Tang Dynasty, A.D. 709-785).

Figure 3 shows eight characters in the poem "Duan Ge Xing" of a famous poet Cao Cao in acient China, which contains the four fonts in odd rows and corresponding hybrids with Yan Zhenqing's calligraphy in even rows. The sizes of the dilation operator and erosion operator are both 3×3 pixels. Several parts of hybrid characters are marked, which imitate a special calligraphy skill "Fei Bai". "Fei Bai" is a phenomenon that part of stroke of a character fades out due to the fast movement of hair brush or the lack of ink. Obviously, the same horizontal stroke in LS'4, WB'4, KT'4 and ST'4 is thinned compared to original four fonts: LS4, WB4, KT4 and ST4. The principled reason resulting in fadeout of strokes is $slope' = 0$ in (2), in other words, the dilation operator is a horizontal line. The more intuitive explanation is that "pads" horizontal stroke with nothing and "cuts" them too much. Moreover, $slope' = 0$ reveals that the slope of Yan Zhenqing's horizontal stroke in the position marked by rectangle in LS'4 is always zero. Horizontal strokes on the top of LS'7, WB'2, WB'7, WB'8, KT'2, KT'7 and KT'8 indicate the slope of Yan's horizontal stroke on the top is always 0. And horizontal strokes on the bottom of LS'2 and KT'2 imply the slope of Yan's horizontal stroke on the bottom is always 0. The joint of two strokes in ST'2 and ST'8 is thinned because Yan's stroke in the direction of $\pi/4$ always occur in the position marked by rectangle.

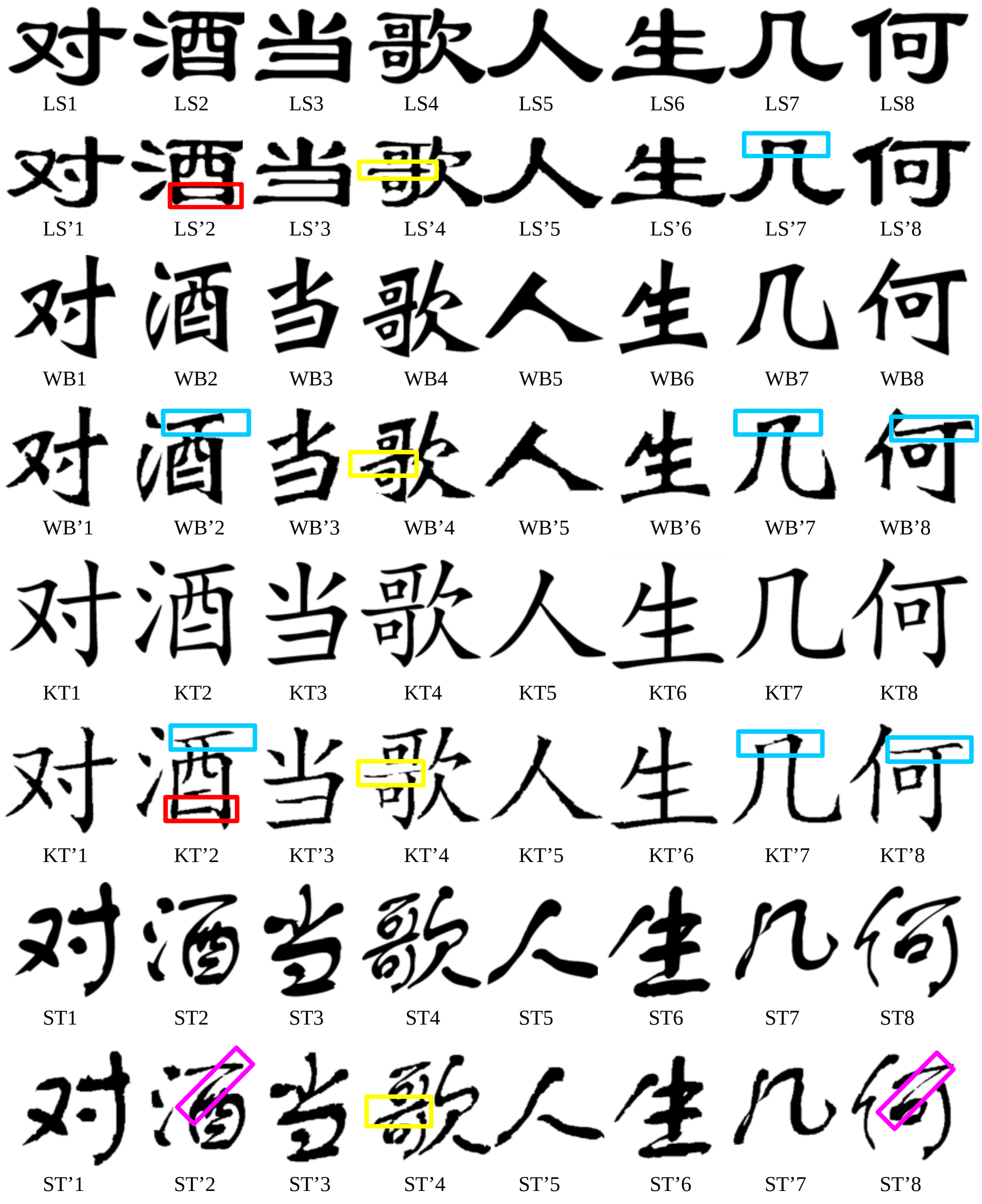

Figure 3: Four fonts and corresponding integration with calligraphy. Odd rows illustrate "Li Shu" "Wei Bei" "Kai Ti" and "Shu Ti" fonts, and even rows exhibit corresponding hybrid characters. Several parts of hybrid characters are marked with rectangle to depict fundamental principles for special effect of calligraphy "Fei Bai". Two sizes of dilation operator and erosion operator are both 3×3 pixels.

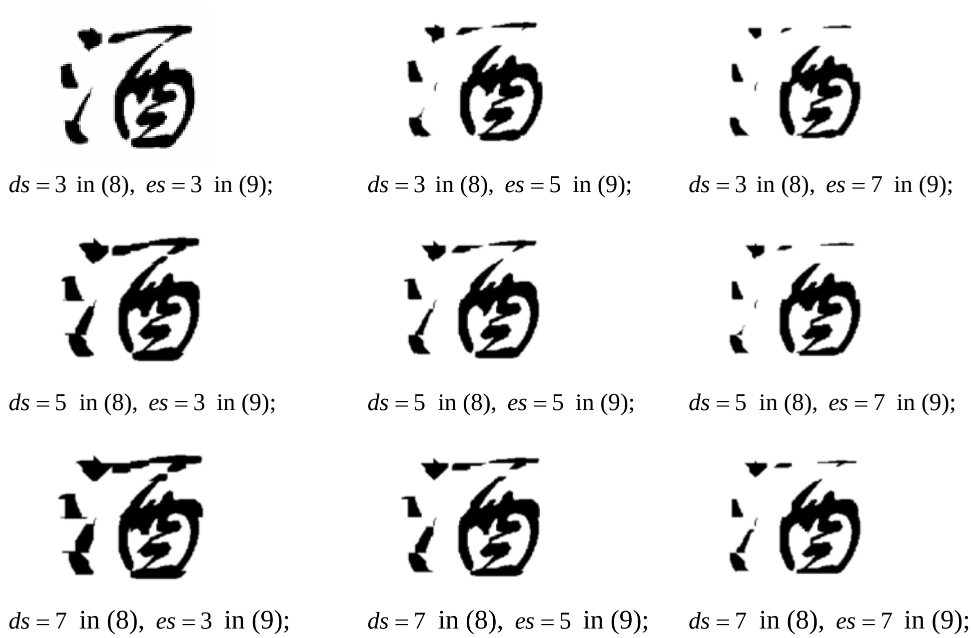

Figure 4: The integration of "Shu Ti" font with Yan's calligraphy adopting different sizes of dilation operator and erosion operator. The ds and the es are size of dilation operator and size of erosion operator, respectively.

To further investigate the influence of the size of morphological operators toward integration of font and calligraphy, the parameters ds and es in Figure 4 were adjusted to generate hybrid character. As Figure 4 shows, nine hybrid character images were generated using various size of dilation operator and erosion operator. In each row, from left to right, the stroke is thinned because the size of erosion operator increases. In each column, from top to bottom, the stroke is thicken with the increase of dilation operator. The left bottom character ($ds = 7$, $es = 3$) imitates another calligraphy skill "Zhang Mo". "Zhang Mo" describes a condition that hair brush holds so much ink that strokes overlap. It employs dilation operator to "pad" strokes so much that it seems too much ink drops down from hair brush to let strokes overlap each other.

5. CONCLUSION

In this work, a strategy is proposed to achieve features fusion from local contour feature of Chinese calligraphy characters and structural feature of font. The local contour feature is defined by Gaussian function, which reflects slope distribution in sub-images of calligraphy characters. In features fusion process, a dilation operator is generated according to the local contour feature of a particular calligraphist, which is used with an erosion operator to adjust boundary of font. Finally a hybrid of calligraphy and font is created by the proposed features fusion strategy. The experimental results demonstrate the created hybrids, which reflect calligraphist writing feature according to the change of stroke width. And two calligraphy skills were imitated by adjusting the size of dilation operator and erosion operator.

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