A Small-Size Chinese Font Display by Perception-Based Grid-Fitting Method

Thou-Ho Chen*, C. T. Huang and L. G. Chen

*Department of Computer Science and Information Engineering
Southern Taiwan University of Technology
Tainan, Taiwan, R.O.C.
Tel: 886-6-2533131 ext. 3121
e-mail: chenchen@mail.stut.edu.tw
Fax: 886-6-2537461

Department of Electrical Engineering,
National Taiwan University
Taipei, Taiwan, R.O.C.

Abstract

This paper presents a perception-based grid-fitting method for Chinese fonts at a size small than 20 points to achieve a high-quality display. The basic idea behind the proposed method is to adopt human visual-based grid-fitting rules that govern the gray-scaling strategy on the cathode ray tube (CRT) screen. The major procedures include super-sampling, adjusting the position and width of strokes, grayscale filtering and sub-sampling. The experimental result shows that the jagged edge induced by the coarse resolution can be removed and the rendition of character details and the contrast are also improved, this reveals that the character's clearness and smoothness can be enhanced for a higher legibility with comfortable reading.

Keywords: Chinese characters, display, font, grid fitting

Contact author: Thou-Ho Chen

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1. Introduction

Generally, bi-level (i.e., black and white) characters suffer from aliasing (the jagged and staircases) at the low resolution typical of most displays, where most PC and workstation interfaces support the display of only bi-level characters). Traditionally, grayscale technique is introduced to compensate for the poor resolution of bi-level display fonts [1]-[9]. The idea is to remove the jaggies induced by the coarse resolution and to improve the rendition of character details. However, the filtering and sampling strategies used to generate grayscale characters at display resolution will produce poor-contrast characters. According to research in psychophysics [10], poor contrast does not ultimately impair legibility, but there is a comfortable reading problem that depends on the degree of contrast, as well as on the spacing between strokes of a character. Display screen made of such alphabet characters appears fuzzy, particularly at font sizes smaller than 12 points. The research in [11] adopts some anti-aliasing technique for displaying high quality Chinese characters. But, the fuzzy phenomenon will become apparent below 20 points for Chinese characters due to the complexity of strokes.

To improve the fuzzy effect for the alphabet characters, [9] proposes a perceptually tuned grayscale font by incorporating the expertise of type designers into rules for character's outline weight and phase control. It also points out that all linear filtering methods [3][4][6][14] assign different contrast profiles to the same character parts. This leads to fuzzy characters regardless of the filter because it violates one of the design rules that experienced type designers used to ensure high-contrast type: all identical character parts should have an identical look. However, in Chinese characters, many strokes and subparts of the character have similar or same shapes but different sizes within various characters for the purpose of looking beautifully. So, the previous gray-scaling methods suitable for alphabet characters may be not appropriate for Chinese characters. This motivates the research to develop a high-quality display Chinese characters at a font size small than 20 points, where high-quality means both clearness and smoothing should be improved through enhancing contrast/clearness and anti-aliasing, respectively, to achieve a high legibility.

The approach proposed is to synthesize the high-contrast rules of alphabet type designers and appropriate filtering and sampling strategy into a small-size oriented gray-scaling display method for Chinese characters. The major procedures of the developed algorithm include super-sampling, adjusting the position and width of strokes, grayscale filtering and sub-sampling.

2. The Proposed Display Algorithm

2.1 Display Features of Small-Size Fonts

In general, a character of font size below 20 points means the width of the stroke is small than one pixel grid and the strokes may be abutting each other. In such a small-size font, there will be stroke abutting and stroke breaking problems if only bi-level gray is used. This drawback appears to be significant for the outline font. Thus, the bit-map font is adopted for the purpose of high legibility and high clearness, such as small-size Chinese characters in MS-Windows. Inherently, the bit-map font suffers from large memory storage and jagged edge, which will limit the scaling flexibility, and hence is not frequently utilized for most of PC interface and display windows. Therefore, outline format is widely used in Chinese display font on PC, and then this research focuses on such a font format which is generated by parametric curves.

2.2 The Display Algorithm

Fig. 1 shows the proposed display algorithm for small-size Chinese character. At first, the input is the character's outline curves for current True-Type font [13][14] that are widely used in PC Windows or Mac.. For the input, the curve format of describing a character is classified into two types: one is global curve (i.e., an integration of some strokes) and the other is stroke curve (i.e., subpart of a character). If the character's outline format belongs to the stroke-curve type, the stroke curve will be shifted to the appropriate grid according to the visual hint processing information, include stroke-width adjusting, spacing between strokes, and stroke grid-fitting information. Otherwise, the global curve should be moved to fit the appropriate grid based on the largest amount of straight grid-lines fitted, while the effect is inferior to that of the stroke-curve type. The above two grid-fitting steps all focus on the contrast enhancement. This is the basic ides of improving the clearness especially for small-size Chinese characters. Besides, stroke-width adjusting and stroke spacing also play an important role of clearness improvement. Fig. 2 shows the shifting and width adjusting of the stroke curve and the shifting of the global curve. Super-sampling will reduce aliasing artefacts by increasing the frequency of the sampling grid (i. e., increasing the spatial resolution of the pixel array) and averaging the results down. A low-pass filter is utilized to smooth the jagged curve of a character outline since the classical aliasing artefacts will be caused by the high-frequency information. Sub-sampling, a dual sampling process of super-sampling, is to recover the original number of sampling grids. Finally, grayscale adjusting is used to enhance the contrast of output display font by gamma correction [7].

2.3 Grid-Fitting for Stroke Curves

Adjusting the stroke to the appropriate grid can enhance the contrast and improve the clearness of strokes, as shown in Fig. 3. It is obviously that the contrast of the stroke-shifted character can be enhanced for the grayscale font. Based on the visual hint processing information, The algorithm of grid-fitting for stroke is divided into three procedures: (1) Find the position and kind of the stroke; (2) Shift the stroke to fit the appropriate pixel grid. (3) Adjust the width of the stroke and the space between strokes. The three procedures are described as follows:

Procedure 1

step 1: Find the coordinate of the stroke: (MAX_x, MAX_y) and (MIN_x, MIN_y)

step 2: Find the stroke vector (dx, dy) : $dx = MAX\_x - MIN\_x$, $dy = MAX\_y - MIN\_y$

step 3: Judge what kind of the stroke:

(i) If both dx and dy are small than 1/7 of the character size, the stroke is regarded as a point-stroke.

(ii) If both dx and dy are very similar and larger than 1/2 of the character size, the stroke is regarded as sloping-stroke or bending-stroke.

(iii) If the difference between dx and dy is larger than 2 times the minimum of dx and dy, the stroke is regarded as the straight stroke, including the vertical-stroke or horizontal-stroke.

In step1 of the above procedure, (MAX_x, MAX_y) means the upper-left coordinate of the stroke and (MIN_x, MIN_y) means the lower-right coordinate of the stroke. Then, the maximum and minimum coordinates of the stroke is utilized to obtain the vector (dx, dy) that is further used to distinguish which type of the stroke, such as point-stroke, non-straight-stroke, or straight-stroke. As described in step 3, the following procedure focuses on adjusting stroke position for vertical-stroke, horizontal-stroke and bending-stroke.

Procedure 2

step 1: Find the width of the stroke.

step 2: If the stroke width is larger than one grid size, go to step 5.

step 3: Move the stroke to the nearest grid.

step 4: Go to *step 7*.

step 5: Find the central line of the stroke.
step 6: Fit the central line of the stroke to the central line of the nearest grid.
step 7: *END*

In the Procedure 2, the grid-fitting process depends on the low-pass filter adopted. For both Conical filter and Gaussian filter, the central line of the stroke should be fitted to the central line of the grid in order to obtain the better result. But for Box filter, it is only to shift the stroke to the interior of the grid. After the above grid-fitting process, stroke-width adjusting may be required to further improve the clearness between strokes. The following procedure will adjust the stroke-width for removing the fuzzy phenomenon that is caused by lacking of the space between strokes.

Procedure 3

step 1: Find any stroke pair, in which the space between these two strokes is about one grid size.
step 2: For the stroke pair found in step 1, there are two cases of processing.
  (i) For the straight-stroke pair, such as two horizontal, two vertical, or one horizontal and one vertical strokes, if the space belongs to the boundary area of the grid, the stroke width is half reduced for the both strokes.
  (ii) For the non-straight stroke pair composed of any two strokes among the point-stroke, sloping-stroke, or straight-stroke, excluding the above case (i), if the nearest distance between the two strokes is located around the boundary area of grids, the stroke width will be reduced to a various degree according to the stroke types.
step 3: If he space of the stroke pair described in step1 is more than two grid size, each stroke of pair is widened by one third.

After the first two procedures, the legibility of a character can be re-enhanced through the third procedure. In the procedure 3, the space between these two strokes can be measured with the nearest distance between the two strokes.

2.4 Grid-Fitting for Global Curves

It is a difficult work to achieve an appropriate grid-fitting for the global curves. This is because that there is almost no information about which oriented position of grid fitting is the best. It implies that someone sub-curve of a global curve is fitted to an appropriate grid while other sub-curves may be not. Thus, the effectiveness of enhancing contrast by the grid-fitting strategy is far less than that of the stroke curves. Generally, the degree of legibility of a Chinese character on the display grid scheme will be dependent on the amount of horizontal and vertical lines fitted. If there are more fitted straight lines of grids, the contrast will be more enhanced. The fitted straight line means the straight stroke being shifted to the appropriate grid. Based on the above idea, the grid-fitting process is to move the global curve to the appropriate position through the approach of the largest amount of fitted straight (i.e., horizontal or vertical) lines of grids.

The following procedure will describe the proposed grid-fitting strategy for the global curves.

Procedure 4

step 1: If the number of global curves in one input character is more than one, these global curves will be sent one-by-one to the step 2.

step 2: Shift the global curve horizontally and reduce its horizontal width, alternately, until that there is the largest number of vertical grid lines fitted.

step 3: Shift the horizontally adjusted global curve in step 2 vertically and reduce its vertical width, alternately, until that there is the largest number of horizontal grid lines fitted.

2.5 Filtering

To generate a grayscale character, super-sampling, filtering and sub-sampling are combined, theoretically, to a three-stage process as follows:

Stage 1: A pixel-based character image is sampled at 5 times the original resolution. Then, the generated high-resolution character can be regarded as a virtual image.

Stage 2: The virtual image is then low-pass filtered with a 5*5 box filter.

Stage 3: The filtered image is sub-sampled at the final stroke resolution to derive the grayscale character.

In Stage 2, it is assumed that the gray-level is from 0 to 255, hence each coefficient of the filter will be 10.2 (i.e., 255/25) and the same for all coefficients. Stage 2 and 3 mean that when the real (low resolution) image is generated from the virtual (high resolution) image for each pixel value, a region in the virtual image should be taken into account. The extent of that region determines the frequencies involved in the lowpass filter operation, also the process is called digital convolution. Fig.4 shows the lowpass filtered font from super-sampled character and the final result after sub-sampling. For clearness of demonstrating the filtered result, Fig. 4(a) and (b) are n times the original resolution, while Fig. 4(c) is the final result through sub-sampling to the original resolution and Fig. 4(d) is zoom-in of Fig. 4(c).

The smoothing filter is usually utilized to cope with the jaggies and then generate a comfortable reading effect. With four different smoothing filters, Fig. 5 shows the comparison of filtered characters without grid-fitting process and with grid-fitting for strokes. In the figure, the top line shows the grayscale characters without grid-fitting and the second, third and last demonstrate the filtered grayscale characters with grid-fitting process through Box filter, Conical filter, and Gaussian filter, respectively. It shows that both Box and Gaussian filters have significant superiority on contrast. This reveals that the Box filter is superior over others when a low-complexity grid-fitting process with acceptable result is considered..

3. Experimental Result and Analysis

Without loss of generality, Ming font and Kai font (i.e., brush font) are adopted to realize the proposed display algorithm. Fig. 6 shows four display Ming fonts through bi-level, Microsoft Plus grayscale, box filter, and the proposed method. In Fig. 6(a), the bi-level character is provided by dot-matrix Ming font in Chinese Window 95, and it looks very clear but jaggy. Fig. 6(b) shows the grayscale font of Microsoft plus for Chinese version, and it has six gray levels. Since the straight line including vertical and horizontal lines, is realized by only one pixel width and with the top gray level (i.e., dark). This results in being un-average on gray level distribution, i.e., un-symmetric contrast. Processing directly with a box filter, Fig. 6(c) demonstrates a more legible and smooth-looking display than both Fig. 6(a) and Fig. 6(b). Obviously, the proposed method gives a better display result, as shown in Fig. 6(d), than others, by enhancing legibility and smoothing.

Most strokes of Ming font can be viewed as straight lines, hence it is easy to move the stroke to fit the nearest grid. But most strokes of Kai font are non-straight or bending, it is intractable to fit the central line of the stroke to the center of grid. Therefore, it is difficult to achieve high contrast and high legibility for small-size Kai font. Fig. 7(a) shows the display of bi-level Kai font supported by Chinese Window 95 and Fig. 7(b) describes the display result of the proposed method, where the font size in Fig. 6 is 16*16 points. The bi-level Kai font bears high clearness contrast but low legibility. The proposed method smoothes away the jagged edge of character's outline to increase the legibility and move the global curve to fit the appropriate grid to enhance the contrast. For most of current products of Chinese fonts, the capabilities of width adjusting and grid-fitting are not automatically adaptive. By using both gray-scaling processing and contrast-enhancing technique for Kai fonts, high contrast and legibility can also be achieved to a certain degree. However, the proposed method can obtain an excellent display quality for Ming font.

4. Future Trend

As discussed in the above section, the acceptable display quality of Ming font through the proposed algorithm is more than that of Kai font. If the stroke-width adjusting and the grid-fitting is performed by manual processing for Kai font, the display quality will be the best. This is because the contrast can be largely enhanced and space between strokes can be increased significantly. The both improvements by manual processing will make the display quality of Kai font superior to that of the proposed method.

Fig. 7 shows comparison of the proposed method and the manual processing for displaying Kai font. However, no any displaying methods can overcome the intractable problem that the display grid number of horizontal or vertical is less than the total number of strokes plus the spacing grids of a character. The basic idea of solving the above problem is to reduce partial strokes of a character. The benefit of stroke-reduction is illustrated in Fig. 8, where the bold is the result after stroke-reducing. It is obvious that the grid number required by the stroke-reduced character is reduced significantly. Although the manual processing method can generate the best quality of displaying and the stroke-reduction technique can solve the problem of displaying numerous-stroke characters. Anyway, the above both methods will need intensive and complex computations and very much effort.

5. Conclusions

This research develops a high-quality for Chinese characters at font sizes small than 20 points. The major techniques of the proposed method include gray-scaling and grid-fitting. The proposed gray-scaling technique is to use gray levels to compensate for the poor resolution of bi-level fonts in order to reduce the jagged edge. To improve the legibility of small-size fonts, the research is to adjust the stroke's width and fitting the stroke to the appropriate grid to enhance the contrast. However, only the manual processing can achieve the best display quality and the stroke-reduction should be considered when the grid number is less than the number of strokes plus spacing grid of one character, especially for characters of numerous strokes.

Acknowledgment

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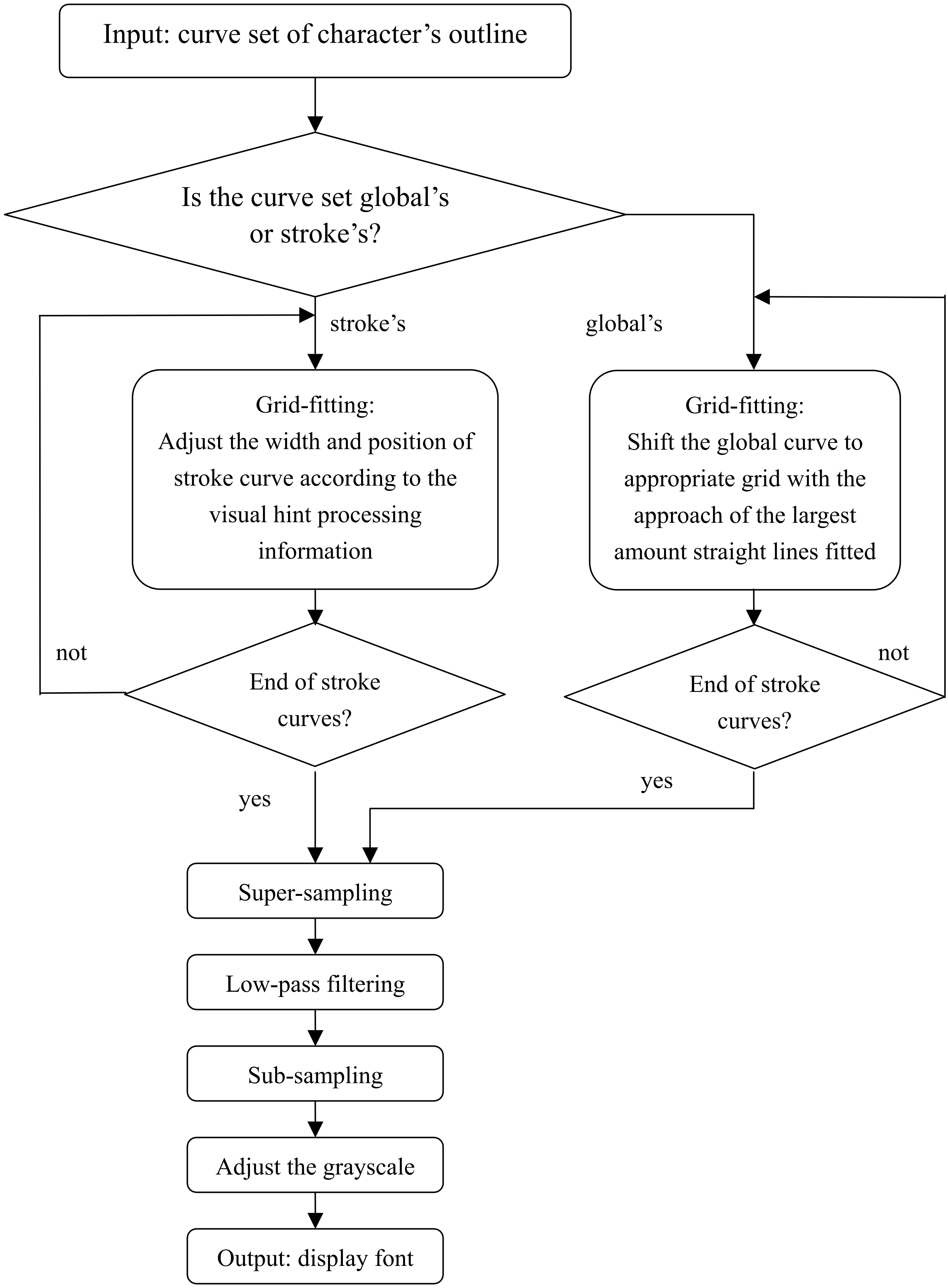
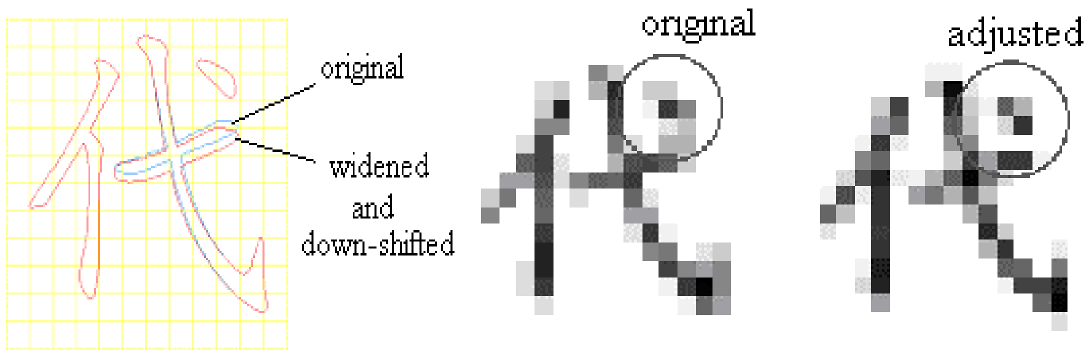
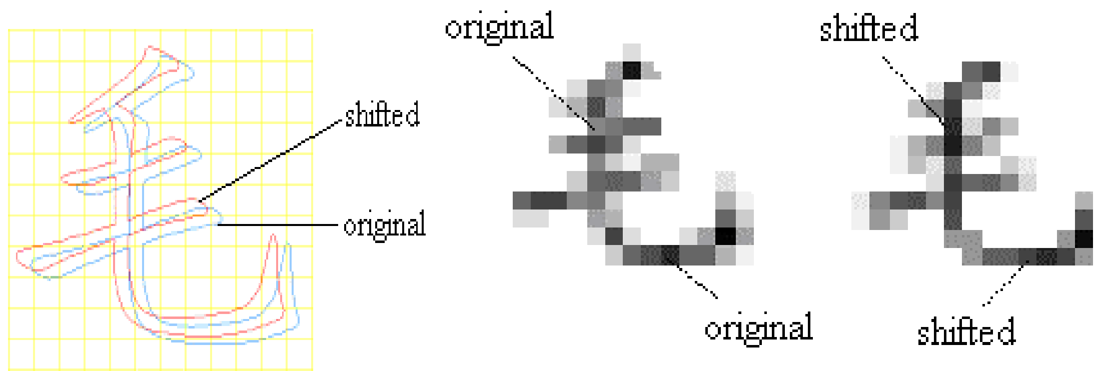


Fig.1. The proposed display algorithm for small-size Chinese characters.

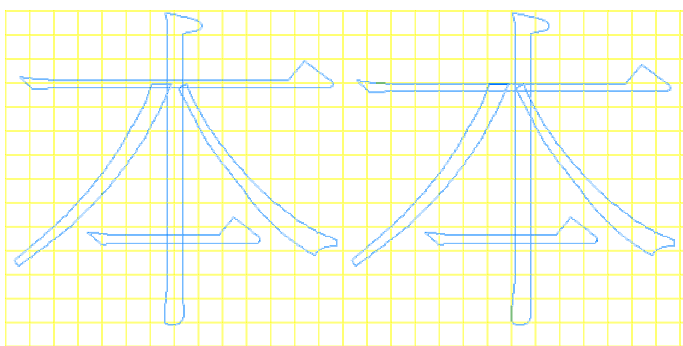


(a)

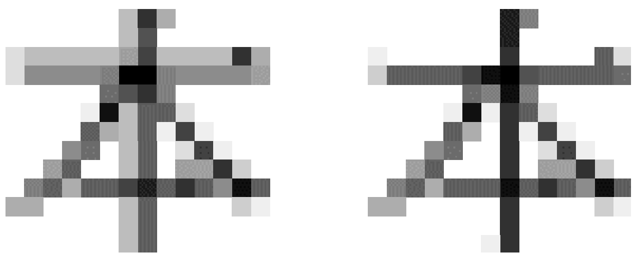


(b)

Fig.2. (a) Shifting and width-adjusting of the stroke curve; (b) Shifting of the global curve.



(a)



(b)

Fig.3. Grid-fitting scheme: (a) the left is original and the right is the stroke-shifted form. (b) grayscaling for (a) .

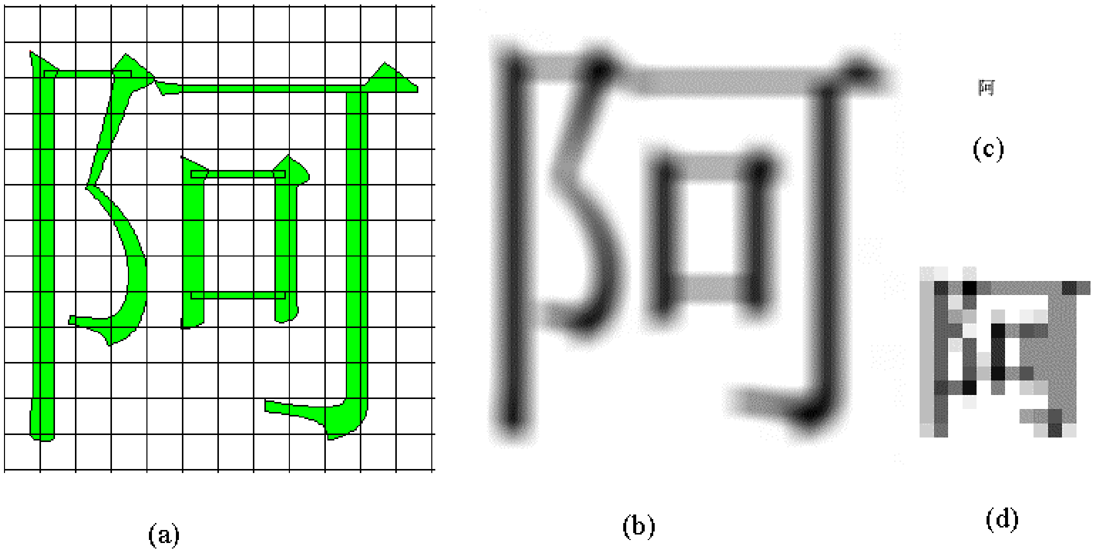
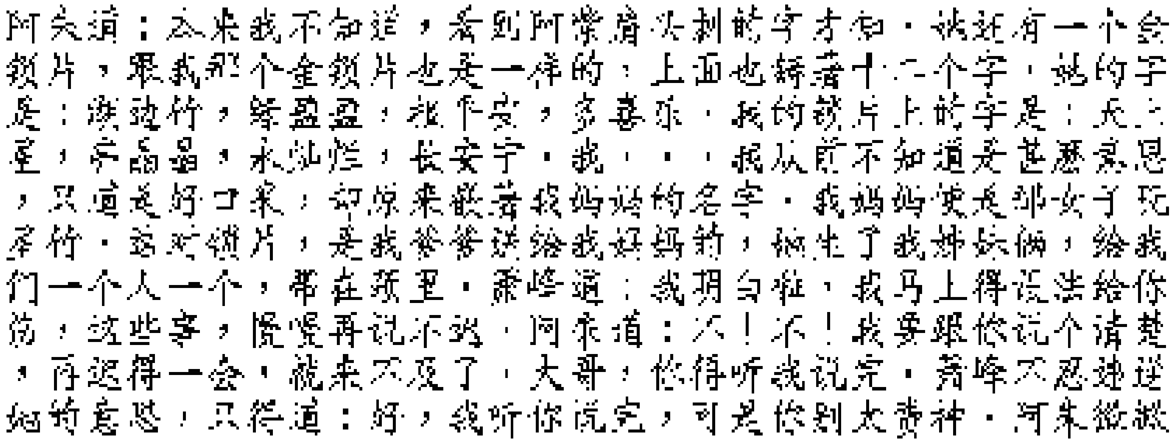


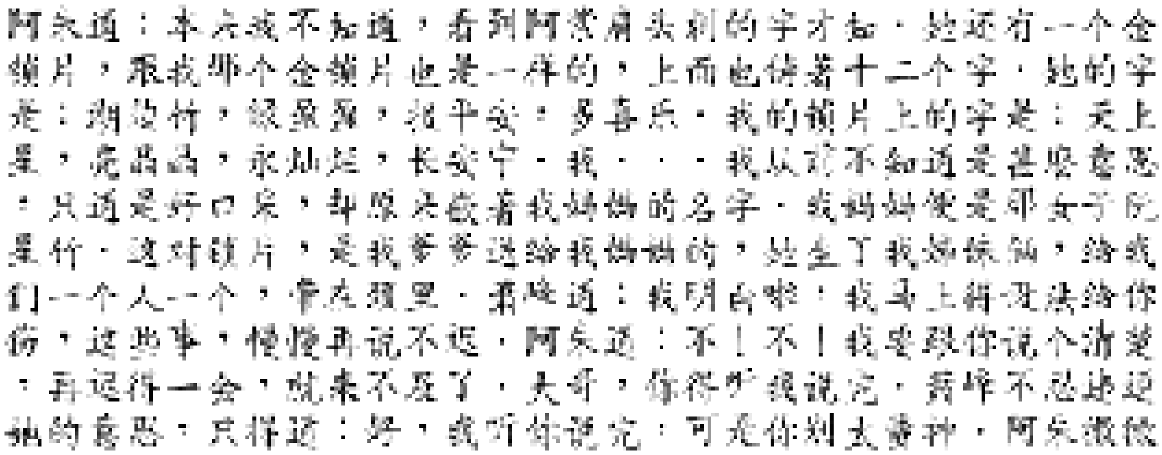
Fig.4. Sampling scheme: (a) super-sampled character in n times the original resolution (virtual image) ; (b) Lowpass filtered character; (c) Sub-sampling to the original resolution; (d) Zoom-in of (c) .

Fig.5. Comparison of the filtered characters: the top line denotes the grayscale character without grid-fitting; the second uses Box filter after grid-fitting; the last uses Gaussian filter after grid-fitting.

Fig.6. Four display of Ming characters with: (a) bi-level; (b) Microsoft Plus grayscale; (c) box filter; (d) the proposed method.



(a)



(b)

Fig.7. Two display of Kai characters with: (a) bi-level; (b) the proposed method.

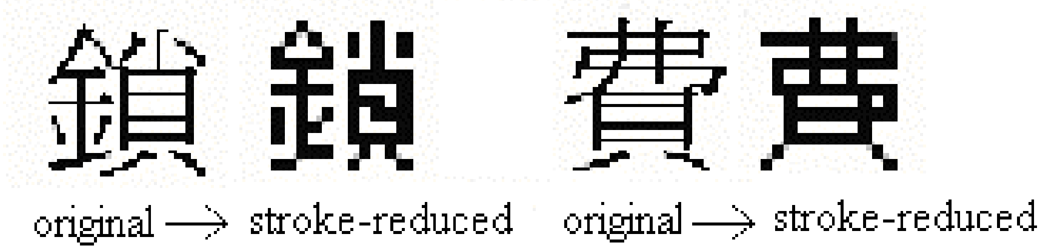


Fig.8. Example of stroke-reduced characters