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Computer-Aided Design AND APPLICATIONS

Design and Evaluation of Handwritten Traditional Chinese Fonts Reflecting Human-like Writing Characteristics via Computer-Mediated Communication

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Abstract. Handwriting reflects an individual's personality and emotions. However, with the rise of social media, handwritten messages have been largely replaced by digital communication, which relies on emojis and stickers to convey emotions. Whether these digital symbols can fully capture human expression remains uncertain. Significant efforts have been made to develop handwriting-based fonts, but existing approaches produce fonts with uniform glyphs for each character, lacking the natural variation found in human handwriting. To address this limitation, we developed InkFontify, a prototype that generates handwriting fonts with multiple glyph variations for the same character using OpenType technology. The fully functional system includes a program for generating writing templates, allowing individuals to handwrite Chinese characters with variations, as well as an algorithm that processes these handwritten characters into computer fonts. The system embeds rules to replicate human-like inconsistency. The resulting innovative fonts can be installed in commercially available word processing software. A user study was conducted, and the results demonstrated that displaying variations of the same character effectively enhances the perception of real human handwriting. This suggests that incorporating multiple glyph styles for a single character improves the handwritten appearance of fonts.

Keywords: Text Communication, Computer-Mediated Communication, Chinese Calligraphy, Handwriting Font, FontForge, Contextual Alternates
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1 INTRODUCTION

Handwritten messages often provide a personal touch that enhances the communication. However, this personal element is typically absent in computer-mediated communication. When writing letters, postcards, or memos, both the words and their presentation reflect and express one's personality and emotions at the time of writing. Consequently, the handwriting style of an individual can significantly enhance the efficacy of text communication. However, with the advances of digital technology, email and social media have replaced handwriting with computer fonts and emotional expression with emojis or stickers. However, it remains uncertain whether computer-generated graphics like emojis or stickers can truly convey one's feelings [1].

Various handwritten fonts have been developed, and nowadays it is possible to create a personal font using different methods that reflect an individual's handwriting style [7],[9]. However, the advantages of computer-generated text, such as precision and consistency, contrast with the unique characteristics of human handwriting. The handwriting differs in size, stroke, and ink color due to variations in writing speed and pressure. It is reasonable to state that humans can't write the same characters identically. Inconsistency is therefore identified as a key characteristic of handwriting [4]. In this paper, we present an innovative method for creating personal handwriting fonts that capture the natural variability found in human handwriting.

The prototype features a program for creating writing paper with grids for Chinese characters, an algorithm to convert scanned handwritten characters into fonts, and software to embed rules into these fonts. These fonts can be installed in word processors like Microsoft WORD to display different glyph styles for consecutive identical characters, mimicking human inconsistency. Various users were invited to create their personalized fonts using our prototype, and a perceptual experiment was conducted to demonstrate the effectiveness of inducing the perception of human-like handwriting.

2 METHODOLOGY

OpenType fonts offer several features that allow them to select different glyph styles for the same character [5]. It was initially developed to demonstrate the graphical presentation for English calligraphy, such as ligature substitutions for unique glyphs in "ll", and contextual substitution for flourishes in specific locations, such as "fragile" as shown in Figure 1. This paper employs contextual substitution to exhibit different styles of individual characters in a handwriting font. The font retains various glyph styles for certain characters and displays them according to rules defined through programming.

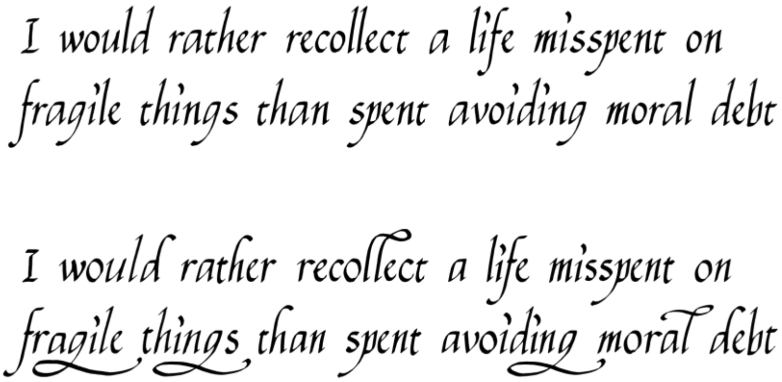

Figure 1: OpenType feature in English calligraphy.

A prototype named InkFontify was designed and developed using Python [10]. The OpenCV library in Python was used to help with image recognition. The prototype has two main functions: generating writing papers to facilitate the recognition of handwritten Chinese characters and processing these characters into fonts. Figure 2 presents the interface of InkFontify.

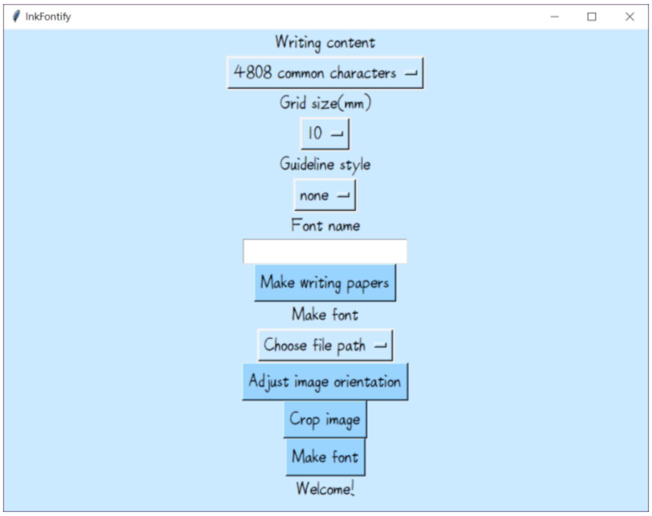

Figure 2: Interface of the InkFontify.

Figure 3 illustrates the process flowchart for creating a font using InkFontify. The process involved four distinct stages. The initial stage aimed to generate the writing paper. The subsequent stage adjusted the orientation of the scanned writing paper. The third stage involved cropping individual images of each character from the writing papers. Finally, the fourth stage formulated the rules for displaying different glyph styles and converted the images into a font.

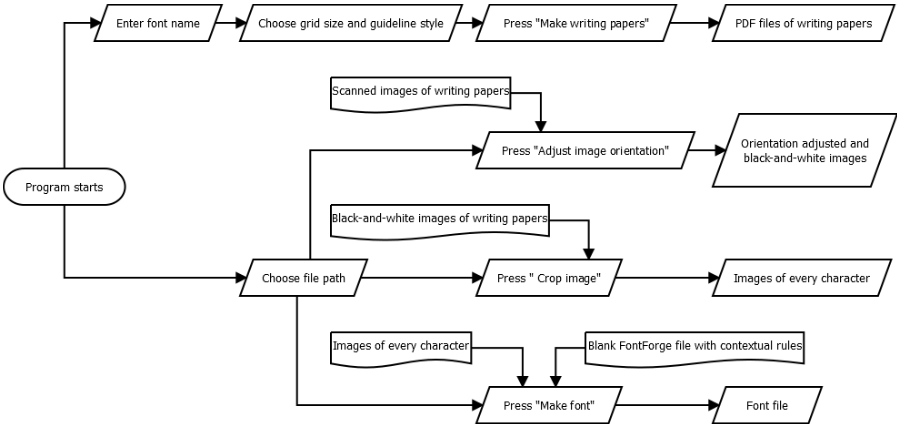

Figure 3: Flowchart of the InkFontify.

2.1 Make Writing Papers

The fundamental concept of this human-like handwritten font is to replicate the natural variability of real handwriting in the displayed text. Thus, gathering variations of frequently used handwritten characters is essential. The system's first step is to generate writing templates designed to capture actual handwritten Chinese characters, with some characters having one or two variations from the user.

To begin, launch InkFontify and enter the desired font name. Next, choose the grid size (8mm, 10mm, or 12mm) and the guideline style (none, four-square, or nine-square). Then, click "Make writing papers." Based on the selected settings, three PDF files of writing papers will be generated.

As illustrated in Figure 4, a page of writing paper features a grid of square boxes with preferred size and preferred subdivision guidelines. On top of each box, a Chinese character features that prompts the user to handwrite it in the box. A QR code, situated at the bottom left corner, aids InkFontify in calibrating the scanned handwritten paper for analysis and processing.

The first set of writing papers includes 4,808 commonly used Traditional Chinese characters, such as "門 (door)" and "快 (fast)," as defined by the Ministry of Education [2]. While some methods generate Chinese character fonts from just a few samples [6], [8], we explore the idea that creating a personalized font from one's handwriting can foster a stronger emotional connection for the user. To achieve this, selected characters are written one or two additional times to introduce stylistic variations. Three PDF files of writing papers are generated, corresponding to the original, variation 1, and variation 2 styles of glyphs. Each PDF file differs in sorting methods and character selection ranges. The first PDF file contains all characters from the basic writing material, sorted by frequency in ascending order. Since handwriting tends to improve with practice, high-frequency characters such as "我 (I)" and "有 (have)" are written later, resulting in a more refined final appearance in the font. The second PDF file includes the top 520 characters from the basic writing material, sorted by frequency in descending order. This ensures that high-frequency characters appear multiple times, allowing for varied glyph styles when they recur. The third PDF file consists of the top 200 characters, also sorted in descending order of frequency. As a result, some characters have only one style, while others feature two or three variations.

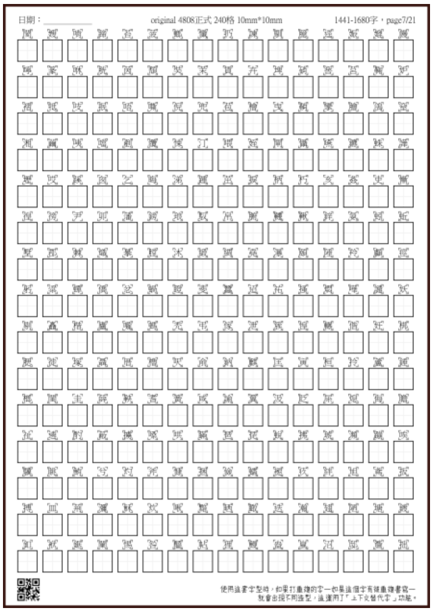

Figure 4: Sample page of writing paper.

The typical writing paper for practicing Chinese Brush Calligraphy is preformatted with square boxes, each subdivided into an equally sized 3 by 3 grid, comprising a total of 9 smaller squares. A preliminary study on handwriting using a pen, pencil, or fountain pen—primarily for communication rather than artistic expression—reveals that when writing Chinese characters freehand, the characters tend to be taller than they are wide. This characteristic consistently results in a width-to-height ratio that is less than 1. As illustrated in Figure 5, the height-to-width ratio of each character in a sentence was analyzed with the boundingRect function in OpenCV. The height-to-width ratio of 17 out of 25 characters was less than 1. To address this issue, the preformatted grid in writing papers employs a rectangular box with a 9:10 ratio, as depicted in Figure 4.

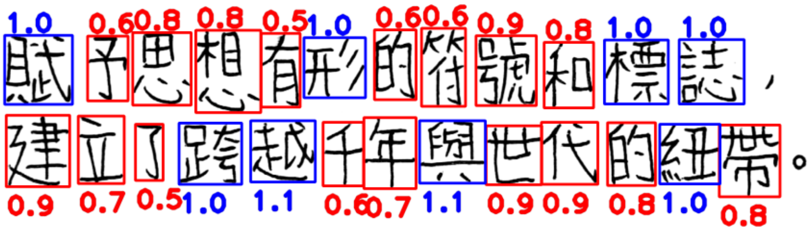

Figure 5: Example of height-to-width ratio for handwritten Chinese characters.

To create content that can be processed by InkFontify, print PDF files of writing papers, and complete writing. Scan each page as a digital image, as Figure 6(a) illustrates. InkFontify created three empty folders for each PDF file; images of each page need to be saved to the corresponding folders.

2.2 Adjust Image Orientation

The pages might be tilted when printing or scanning, reducing the quality of the font. Thus, InkFontify will adjust image orientation. InkFontify detects the horizontal lines of the QR code on each image with the QRCodeDetector function in OpenCV, and calculates their tilt angle with math.degrees function in Python, and adjusts the image orientation accordingly. As illustrated in Figure 6(b), the image is binarized and saved as a new file. Inkfontify reads QR codes, which contain page numbers, and names the files.

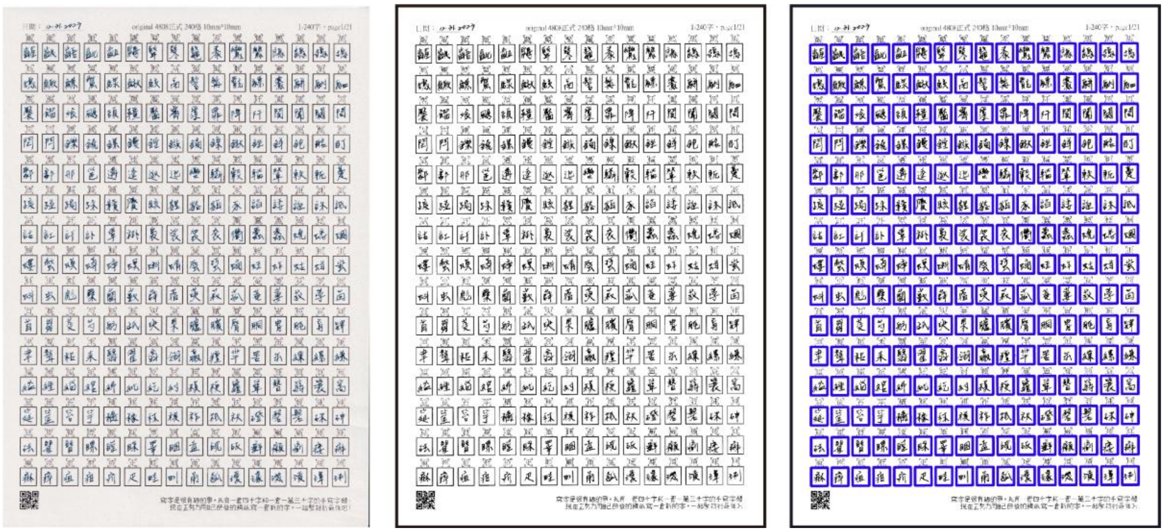

Figure 6: (a) scanned image, (b) orientation and color adjusted, (c) grid detected.

2.3 Crop Image

Each character on the scanned page image must be saved as an individual image. The InkFontify detects the grids for each character and crops them accordingly. Since many Chinese characters, such as 回 and 國, have a square-like structure, the grid size is carefully constrained during detection. The size of the QR code matches the height of the grid. The prototype uses the boundingRect function in OpenCV to detect the QR code size and identify grids with the same height. As illustrated in Figure

6(c), the prototype detects the grids and marks them with blue hollow squares. Each grid is then cropped into an individual image.

2.4 Adjust the Center of Mass of the Character

When writing a sentence, there is a tendency for sequential characters to shift gradually, causing the sentence to tilt at an angle unconsciously. The angle might be minor or hardly noticeable in the original handwriting. Still, when the characters are extracted and rearranged in a new order, the resulting line may exhibit a zigzag pattern. Field tests revealed that the aforementioned handwriting tendency is also evident when users fill in the grids on the writing paper. The written characters are not always perfectly centered within the grid when saved as individual images. To create a font that is comfortable to read when characters are combined in various ways to form sentences, the center of mass for each character must be aligned.

Figure 7 illustrates the solution: after each font is cropped and created from the scanned page, InkFontify detects every stroke in the character with the drawContours function in OpenCV and calculates the center of mass for each (marked as red dots in Figure 7). The overall center of mass of the character (marked as a blue dot in Figure 7) is then determined by calculating the center of mass of all the red dots. By employing this approach, the presented sentence can avoid the abrupt shifts between characters, as illustrated in Figure 8.

Figure 7: Calculation result of the center of mass in a character.

Figure 8: Comparisons of the sentence without (a) and with (b) the adjustment of the center of mass.

2.5 Make Font

The font editor FontForge is used to access the OpenType feature [11]. The images of each character are then converted into SVG files and imported into a blank FontForge file. The font was encoded in Unicode BMP [3], non-repeating characters are placed in their corresponding Unicode slots, while new slots are created for repeating characters. The OpenType feature is accessed through the lookup function in the file.

The lookup function includes two single-substitution files and one contextual-chaining substitution file. Each single substitution file includes a list of repeating characters with the same variation number: variation 1 of the repeating characters is placed in the first single substitution file, and variation 2 is placed in the second single substitution file. The contextual substitution contains rules that determine which variation style will be displayed. The file includes two rules designed by the researcher: "x | x@<1> |" and "x | x@<1> x@<2>|". The first rule means that if there are two characters in a sentence, and the first character uses the original style, the second character will display in variation 1 style. The second rule means that if there are three characters in a sentence, the first character will use the original style, the second character will use variation 1, and the third character will use variation 2. Figure 9 illustrates the effect of the rules. The prototype then exports the FontForge file as a TrueType file [4].

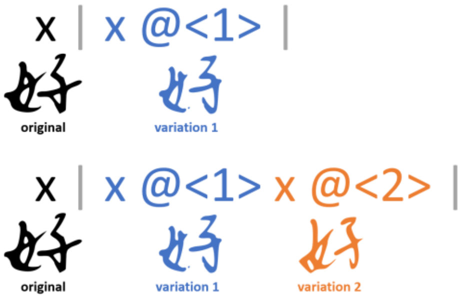

Figure 9: The contextual substitution rules.

3 DESIGN IMPLEMENTATION & EVALUATION

The evaluation study was divided into two sections: prototype testing and perceptual study. Prototype testing assessed the practicality of the prototype, while perceptual experiments investigated how fonts with contextual features influence human handwriting perception.

3.1 Prototype Testing

Twenty participants, comprising 16 women and 4 men, volunteered to participate in this study. Their ages ranged from 21 to 68 years, with an average age of 33 years. All participants reported proficiency in writing Traditional Chinese. The participants were tasked with writing approximately 4800 characters within a month. Upon completing the study, they would receive a personalized handwriting font. Each participant was provided with three sets of writing papers, along with detailed instructions. To ensure that the writing papers could be processed by InkFontify, participants were required to return their first completed page. Two days later, they would receive a font file generated from the first page. Once all writing was completed, participants returned their writing papers to the researcher. Two weeks later, they received their finalized handwriting font files.

InkFontify successfully created twenty handwriting fonts, as illustrated in Figure 10. These fonts automatically selected appropriate glyph variations for repeated characters. Characters marked with solid squares (手) represent “hand,” and each character displays a distinct glyph style.

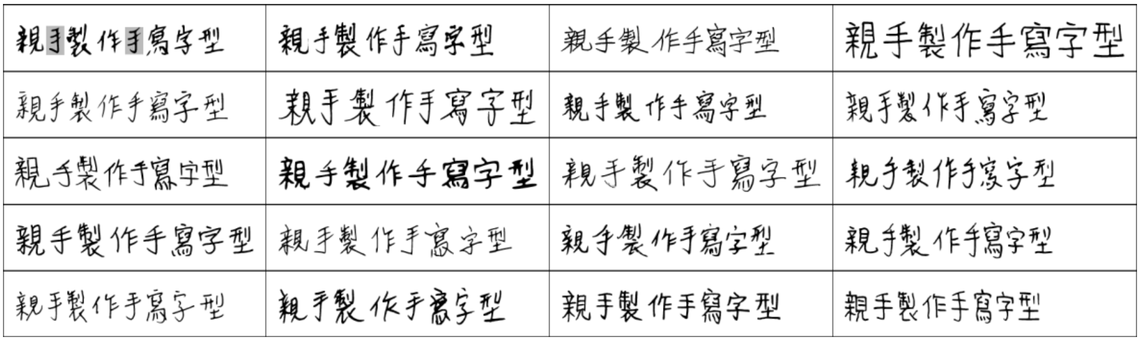

Figure 10: Twenty fonts created by the prototype.

3.2 Perceptual Experiments

To assess two key features of the handwritten font generated by InkFontify—the creation of a computer font based on an individual's actual handwriting and the ability to display the same characters with different variations—an experiment was conducted to evaluate their perceptual effects. As illustrated in Figure 11, a paragraph was printed on A4-sized paper using the fonts "BiauKai," "HanziPen," "Lingwei," and "nanTai" with contextual alternatives, as well as "nanTai" without contextual alternatives enabled and a real handwriting sample. Three commonly available fonts—"BiauKai," "HanziPen," and "Lingwei"—represent a range of computer fonts, from standard typewriter-style to those that mimic human-like handwriting. In contrast, the font "nanTai" is generated by InkFontify using actual handwriting. To further investigate whether the variation of the same characters enhances the perception of human handwriting, two paragraphs were printed using the "nanTai" font, one with and one without the contextual alternative option enabled. Additionally, a real handwriting sample, written by the same person who created the "nanTai" font, was included as a baseline condition.

Figure 11: The same paragraph printed with the following fonts: (a) BiauKai; (b) HanziPen; (c) Lingwei; (d) nanTai with variation; (e) nanTai without variation; and (f) actual handwriting.

Two evaluation methods were used: a ten-point preference rating scale and a forced-choice preference assessment. In the preference rating task, participants read each printout and rated how closely it resembled real handwriting on a scale from 1 to 10. In the forced-choice preference assessment, participants were presented with pairs of printouts and asked to select the one that most resembled real handwriting. The total number of selections for each printout was used to establish a preference order. Twenty participants took part in the study, each rating the presented printouts twice and making a forced-choice selection for each pair twice.

Table 1 presents the results of the preference ratings and total selections for each printout of the forced-choice preference assessment. The data indicate that real handwriting was the most preferred, followed by the version printed with "nanTai" contextual alternatives enabled, and then the version with contextual alternatives disabled. In contrast, the typewriter-style font “BiauKai” received the lowest rating, followed by the computer-simulated handwritten fonts “Hanzipen” and “Lingwei.”

The preference ratings closely aligned with the forced-choice preference assessment, as the total number of preferred selections for each printout followed the same ranking. Real handwriting received the highest number of preferred picks (166), followed by "nanTai" with contextual alternatives enabled (157). Statistical analysis confirmed that the differences in preference ratings were significant ($H = 91.265$, $p < .005$), with post hoc analysis indicating that all pairwise comparisons were significant, except between real handwriting and "nanTai" with contextual alternatives enabled. This finding suggests that our newly developed fonts, which incorporate actual handwritten characters and display different variations side by side, can be perceived as authentic as real handwriting.

	BiauKai	HanziPen	Lingwei	nanTai with Variation	nanTai without Variation	Actual writing
Rating	1.00	2.80	5.13	7.88	7.20	8.00
Total picks	0	42	107	157	128	166

Table 1: Comparison between preference rating and forced-choice preference assessment.

4 CONCLUSIONS

The art of handwriting has long been recognized, evident in the practice of calligraphy across diverse cultures throughout history. Handwriting is considered an art because it can convey perceptual feelings beyond the textual content of a document. While computer software and graphical design have become prevalent in document preparation, there is still a growing trend among individuals to practice their handwriting. Therefore, instead of using digital technology to develop a computer font that simulates a personal handwriting, the purpose of this study is to utilize one’s actual handwriting characters to create a personal font. This two-fold objective aims to first explore whether the actual handwritten character can generate more human-like handwriting fonts, and second, to encourage individuals to practice their handwriting to develop more expressive personal fonts. By doing so, we can once again rediscover the joy of calligraphy in the digital age.

To enhance the human-like feel of handwriting, the system incorporates an algorithm that presents nearby characters with different handwritten versions, mimicking the inconsistencies often observed in actual handwriting. The working prototype InkFontify successfully engages participants in creating their handwritten fonts through extensive handwriting. Although further studies are necessary, participants express positive support for the process. Many of them volunteer to print more writing paper when they feel unsatisfied with their initial attempt.

Perceptual studies have confirmed that altering a single character in a font enhances its authenticity, making it appear more human and less artificial. This approach infuses digital communication with more emotion, reminiscent of the heartfelt sentiments conveyed in handwritten letters and characters. This concept can help design human-sense graphics and interfaces.

Although this paper primarily focuses on Traditional Chinese characters, the proposed prototype is adaptable to accommodate characters from various languages. This is because the font is encoded in Unicode BMP, ensuring compatibility with characters from different scripts. Furthermore, the font file can be reencoded in Unicode Full without disrupting the font-creation process, thereby providing support for all Unicode-encoded characters.

In the future, we want to conduct more experiments to explore the elements of human perception in handwriting. We also want to study more OpenType features to make InkFontify fully present more languages.

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REFERENCES

[1] Glikson, E.; Cheshin, A.; Kleef, G.A.v.: The dark side of a smiley: Effects of smiling emoticons on virtual first impressions. Social Psychological and Personality Science, 9(5), 2018, 614–625. https://doi.org/10.1177/1948550617720269

[2] Graduate Institute of Chinese of the National Taiwan Normal University: Chart of Standard Forms of Common National Characters. Ministry of Education, 1978.

[3] Haralambous, Y.: Fonts & encodings. O'Reilly Media, Inc., 2007.

[4] Hsieh, Y.A.; Tai, N.C.: An expressive chat room with personalized fonts mimicking actual inconsistencies in human handwriting. In 2023 International Conference on Consumer Electronics-Taiwan (ICCE-Taiwan), 197-198. IEEE, 2023. https://doi.org/10.1109/ICCE-Taiwan58799.2023.10227039

[5] Kempgen, S.: Unicode 5.1, old church slavonic, remaining problems–and solutions, including opentype features. In Slovo: Towards a Digital Library of South Slavic Manuscripts; Proceedings of the International Conference, 2008, 21–26.

[6] Li, H.T.; Jiang, M.X.; Huang, T.T.; Chiang, C.K.: Font generation and keypoint ranking for stroke order of chinese characters by deep neural networks. SN Computer Science, 2(4), 2021, 324. https://doi.org/10.1007/s42979-021-00717-2

[7] Lin, J.W.; Lin, F.S.; Wang, Y.C.; Ho, J.M.; Chang, R.I.: Fontcloud: Web font service for personal handwritten, ancient, and unencoded characters. In Future Information Technology-II, 2015, 113–119. https://doi.org/10.1007/978-94-017-9558-6_14

[8] Lu, S.Y.; Hsiang, T.R.: Generating Chinese typographic and handwriting fonts from a small font sample set. In 2018 International Joint Conference on Neural Networks (IJCNN), IEEE, 2018, 1–8. https://doi.org/10.1109/IJCNN.2018.8489500

[9] Pan, W.; Lian, Z.; Sun, R.; Tang, Y.; Xiao, J.: Flexifont: a flexible system to generate personal font libraries. In Proceedings of the 2014 ACM symposium on Document engineering, 2014, 17–20. https://doi.org/10.1145/2644866.2644886

[10] Van Rossum, G.; Drake Jr, F.L.: Python tutorial, vol. 620. Centrum voor Wiskunde en Informatica Amsterdam, The Netherlands, 1995.

[11] Williams, G.: Font creation with fontforge. EuroTEX 2003 Proceedings, TUGboat, 24(3), 2003, 531–544.