

CalliShadow: Interactive User Guidance for Calligraphic Practice

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Abstract: The study of calligraphy has always been a challenging problem for people without a Kanji cultural background. It is difficult for novices to understand the balance in Chinese characters, the stroke order, and the stroke thickness. Previous studies have been conducted to guide users to write calligraphy through electrical stimulations and have been made to evaluate calligraphy fonts by recording calligraphy traces through tablet computers. However, the way of electrical stimulation can easily interfere with the beautiful font of learners, and it isn't straightforward for users to restore the real environment of traditional calligraphy learning. In this work, we propose a calligraphy support system by combining image matching, image blending, and projection mapping. Providing users with multiple results similar to current writing, the users are instructed on how to write the correct strokes. Experimental results show that our system can effectively support calligraphy learners.

Keywords: image matching, image blending, calligraphy projection, stroke orders

1. Introduction

Among the practices of writing Chinese calligraphy characters, most learners of calligraphy without any background may write as shown in the left image of Figure 1. The traditional approach of calligraphy practice is to observe Chinese characters in pictures and copybooks. Through the observation and feature extraction of the Chinese characters in the copybook (see in Figure 2.), the learners tried to imitate the writing methods of famous calligraphers like Xizhi Wang, Xun Ouyang and Zhenqing Yan. However, due to the limited ability to understand and master the structure of fonts, the imitation of the fonts has not only significant defects in balance but also the stroke thickness cannot be well grasped. To solve this issue the prolonged and repeated training are usually required. The repeated single training approaches would increase the boredom of beginners and make them lose the confidences. Meanwhile, the traditional calligraphy practice methods cannot inform learners of the correct stroke order. Besides, the writing style in copybooks is so different from the learners that makes the learning be difficult. The writing style of the typeface in a copybook may not be suitable for novice learners.

Figure 1. Novice font(left) and font in copybook(right)

Therefore, our research goal is to propose a multi-style selection, stroke order-guided calligraphy practice support system for beginners without changing the traditional calligraphy practice tools.

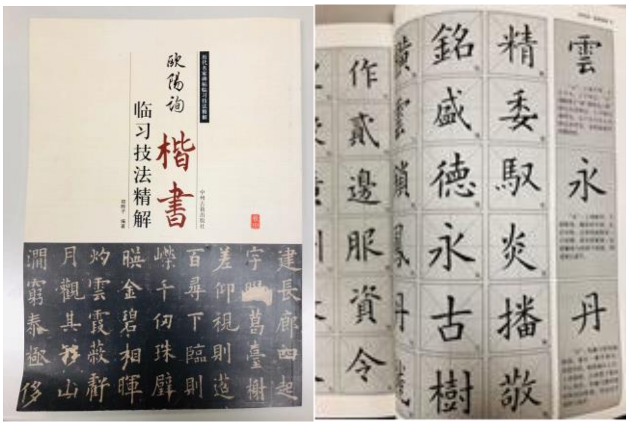

Figure 2. Copybook of Xun Ouyang

In our CalliShadow, a calligraphy support system, we use a new way of projecting mixed images to support calligraphy learners. Compared with previous related research, our system has the following advantages:

- Multi-layer matching calligraphy style recommendation.
- Restore real traditional calligraphy practice environment.
- Including shape detail of each stroke.
- Including stroke writing orders

2. Related Works

There are some calligraphy support systems to guide the novice in calligraphy practice. J. Nonami et al. constructed a transcription learning support system using Japanese brush writing on the tablet without changing the traditional calligraphy practice [1]. The proposed system recorded the calligraphy writing trajectory of beginners in real-time. They designed the font balance system with feedback on font balance to users through the font balance system they designed. N. Muranaka et al. adopted a semitransparent screen and a half mirror to simulate VR space to improve the user's brush movement [2]. Beautifying Font visualizes the pressure and speed of calligraphy strokes and intuitively guides beginners to learn calligraphy [3]. M. Kobayashi et al. implemented virtual writing brush calligraphy with leap motion [4].

There are some training systems for calligraphy and painting. Calligraphy self-training system correct the beginner's wrong

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way of writing by electrical stimulation [5]. ShadowDraw is a system for guiding the free drawing of objects [6]. The proposed system updates outline shadows in real-time, instructing users to continue painting. Z. Lian et al. used the Coherent Point Drift (CPD) algorithm to realize the automatic deformation of Chinese characters [7].

Recently, GAN-based calligraphy graph matching approaches have been explored. A proposed system extracted Chinese character features based on node and edge detection techniques [8]. This system adopted deep learning matching algorithms to change the font style of Chinese characters.

There are several ways to achieve the reproduction of calligraphy traces. F. Peng et al. obtained the writing quality by extracting the user's calligraphy stroke trajectory from the video stream and comparing it with the example template [9]. A calligraphy writing process system realized the animation to reproduce the writing process of ancient handwritten artwork [10].

3. System Design

Callishadow's system design consists of four parts: (1) System Framework, system operation process; (2) Database Generation; (3) The usage of matching algorithm between User's calligraphy and database calligraphy font; (4) According to the degree of matching, select different image weights to blend the pictures.

3.1 System Framework

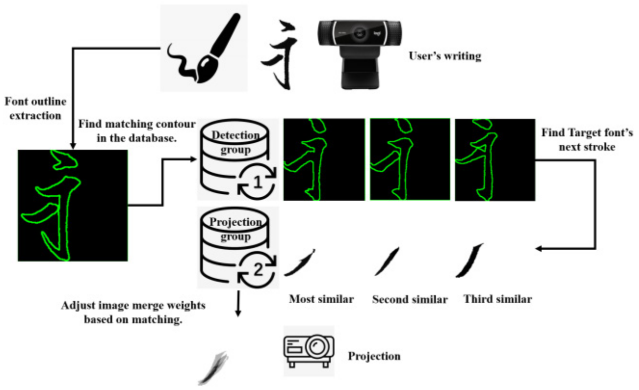

Figure 3. System Framework

Figure 3 shows the system framework of the proposed calligraphy writing support system. Learners use calligraphy brushes dipped in traditional Chinese calligraphy practice ink to write calligraphy on white paper as a system input. The camera captures every state of the user's calligraphy in real-time and matches the user's font data with the font model of database one in real-time and finds several models with higher matching. According to the corresponding relationship established between database 1 and database 2, find the next stroke picture corresponding to the model. According to the level of matching, determine the weight of the image mixing, the matching is high, and the weight is high. The system gives the user a next stroke suggestion through projection as the output part of the entire system.

3.2 Database Generation

The data preparation of the support system consists of four databases. Each set of databases is divided into Chinese characters "Yong" in different states.

Database 4 is composed of 20 "Yong" calligraphy pictures of famous calligraphers in Chinese history, and their calligraphy styles are different. The first stroke of these 20 pictures extracted as database 3. According to the stroke writing rules of the Chinese character "Yong", 20 pictures are divided into 7 writing states of the corresponding style "Yong" respectively and are stored in database 1. Database 2 consists of 20 "Yong" word images with their corresponding stroke segmentation images. (Segmentation of the second to seventh strokes)

Figure 4. A snippet of our database structure

Two detection group databases used to match the user's current calligraphy writing trajectory in real-time. Two projection group databases used to give users feedback on the most suitable writing style and font stroke order. Figure 4 shows the composition and quantity of the database.

3.3 Matching Algorithm

HU moments theory has been proposed half-century ago [11]. When the density distribution function changed, the essence of the image did not change, but the density distribution shifted. Although the values of the moments may change at this time, the invariant moments calculated from the moments still have a translation, rotation, and scale invariance.

Our proposed system adopted the image features of the HU moments with translation, rotation, and scale invariance.

In the continuous case, the image function is f(x,y), then the p + q order geometric moment (standard moment) of the image is defined as:

$$m_{pq} = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} x^p y^q f(x,y)dxdy \quad p,q = 0,1,2\ldots \tag{1}$$

The center distance of p + q order is defined as:

$$\mu_{pq} = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} (x-\bar{x})^p (y-\bar{y})^q f(x,y)dxdy \quad p,q = 0,1,2\ldots \tag{2}$$

Where $\bar{X}$ and $\bar{Y}$ represent the center of gravity of the image.

$$\bar{x} = m_{10} / m_{00} \quad \bar{y} = m_{01} / m_{00} \tag{3}$$

For discrete digital images, use summation instead of integration:

$$m_{pq} = \sum_{y=1}^{N}\sum_{x=1}^{M} x^p y^q f(x,y) \quad p,q = 0,1,2\ldots \tag{4}$$

$$\mu_{pq} = \sum_{y=1}^{N}\sum_{x=1}^{M} (x-\bar{x})^p (y-\bar{y})^q f(x,y) \quad p,q = 0,1,2\ldots \tag{5}$$

N and M in Equations 4 and 5 represent the height and width of the image, respectively.

The physical meaning of each moment:

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- 0th moment (m_{00}): the quality of the target area
- 1st moment (m_{01}, m_{10}): the centroid of the target area
- 2nd moment (m_{02}, m_{11}, m_{20}): the radius of rotation of the target area
- 3rd moment (m_{03}, m_{12}, m_{21}, m_{30}): the orientation and slope of the target area, reflecting the distortion of the target

The normalized center distance is defined as:

$$\eta_{pq} = \mu_{pq} / (\mu_{00}{}^{\rho}) \quad \rho = (p+q)/2+1 \tag{6}$$

Using the second- and third-order normalized center moments, seven invariant moments M1 ~ M7 are constructed:

$$M1 = \eta_{20} + \eta_{02}$$

$$M2 = (\eta_{20} - \eta_{02})^2 + 4\eta_{11}{}^2$$

$$M3 = (\eta_{30} - 3\eta_{12})^2 + (3\eta_{21} - \eta_{03})^2$$

$$M4 = (\eta_{30} + \eta_{12})^2 + (\eta_{21} + \eta_{03})^2$$

$$M5 = (\eta_{30} - 3\eta_{12})(\eta_{30} + \eta_{12})((\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2) + (3\eta_{21} - \eta_{03})(\eta_{21} + \eta_{03})(3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2)$$

$$M6 = (\eta_{20} - \eta_{02})((\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2) + 4\eta_{11}(\eta_{30} + \eta_{12})(\eta_{21} + \eta_{03})$$

$$M7 = (3\eta_{21} - \eta_{03})(\eta_{30} + \eta_{12})((\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2) - (\eta_{30} - 3\eta_{12})(\eta_{21} + \eta_{03})(3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2) \tag{7}$$

These seven invariant moments constitute a set of feature quantities that are used to identify large objects in the image, such as characters, which have better results.

3.4 Image Weighted Blending

The proposed system sorts the database matching pictures from high to low. The image mixture is blended in pairs from the lowest image to the highly matching image, and the weight of the two images is set to 50% each. The system mixes selected matching pictures in the database multiple times to form a mixed picture with gradually decreasing transparency (see Figure 5).

Figure 5. Weighted blending images
Three layers color (left) and three layers gray-scale (right)

4. Experiments

In our experiments, there were 20 participants (5 female and 15 men. The age range is between 22 and 33 years.), which are divided into 2 groups of 10 people each. The participants in groups 1 are familiar with Chinese characters, and participants in groups 2 are entirely unfamiliar with Chinese characters. The 2 groups of experimenters used the traditional practice method of observing copybook pictures to practice calligraphy as a control experiment. The calligraphy practice support system provides projections of 1, 3, and 5 layers of images, as well as projections of gray scale and color font strokes.

The system provides full word writing support projection for experimenters and the next writing support projection based on the current font status of the experimenter. Figure 6 shows the experimenter using colored stroke hints and grayscale stroke hints.

We provide multiple layers of mixed picture projections to give experimenters more imitative choices in the process of practicing calligraphy. At the same time, give experimenters more stroke information to increase the fault tolerance rate of beginners in calligraphy.

Color and gray scale are to verify whether the color hints have an effect on the experimenter.

Figure 6. Comparison experiments of writing guidance projection
With color hints(left) and with gray-scale hints (right)

5. Results and Discussions

The questionnaire results show that the proposed support system is helpful for the balance practice of calligraphy fonts in contrast to the traditional calligraphy practice mode. The participants who are unfamiliar with Chinese characters found that the stroke support to help them understand the composition and writing order of Chinese characters well (see in Figure 7).

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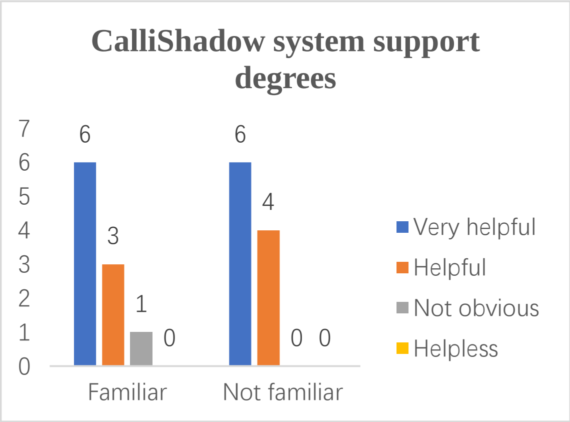

Fig. 7. CalliShadow system support degrees

The results of experimental data show that both learners who are familiar with calligraphy and learners who are not familiar with calligraphy prefer colored single stroke hints. They thought that colored fonts are easier to distinguish between different matching degrees (see in Figure 8).

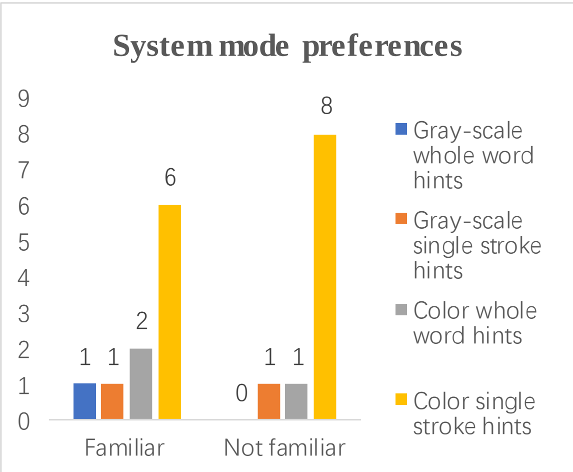

Figure 8. CalliShadow system mode preferences

The results show that the number of layers in the picture will cause disturbance to those who are familiar with calligraphy in Figure 9.　Calligraphy novices would like to choose the number of layers of mixed font image, based on their personal preference.

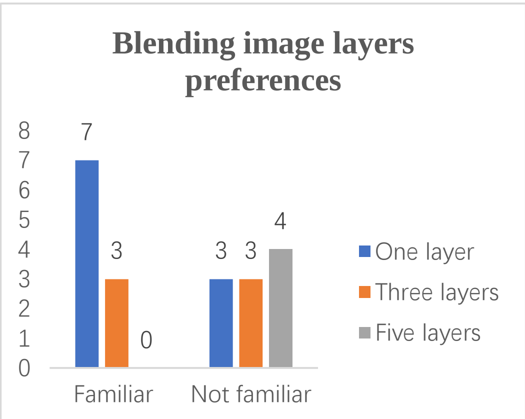

Figure 9. Blending image layers preferences

6. Conclusion

We proposed a calligraphy writing support system with camera-projector system. The system Provide users with multiple results similar to current writing, the users are instructed on how to write the correct strokes. Evaluation experiments show that the system is helpful to understand the stroke order and font structure of calligraphy beginners who are unfamiliar with Chinese characters, and the system dramatically improves the learning effect in the early stage of calligraphy practice.

As future work, the proposed system needs more accurate algorithm to improve real-time matching due to the limitations of the contour matching algorithm.

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