Computer Aided Design of Artistic Chinese Characters

Yongqiang Guo

School of Fine Arts, Anyang Normal University, Henan, Anyang 455000, China, bgong803@163.com

Corresponding author: Yongqiang Guo, bgong803@163.com

Abstract. The development of economic integration process has prompted Chinese companies to compete to integrate into the entire world. Currently, companies need to present their Chinese characteristics to the world. Artistic Chinese characters is a way to visualize the beautify designs. This paper develops a computer-aided design system for the design of artistic Chinese characters based on numerical differential analyzer algorithm. It presents a multilevel mathematical model and uses computer software functions to automatically reprocess, reshape, optimize, and artistic glyphs. Based on the above model, computer-aided design software for Chinese characters of arts and crafts was developed. The interface design and typical procedures of the software were briefly introduced, and the designed shadow and style fonts were displayed. Fonts designed in the system can be used in TV subtitles, advertising, typography, computer animation, large screen display, software packaging and other fields.

1   INTRODUCTION

With the transformation and improvement of the public aesthetic perspective, Chinese character elements in traditional Chinese culture are the more widely used form elements in modern design. It has irreplaceable visual effects compared with other design elements and design methods. The accelerated development of the world economic process has prompted Chinese companies to integrate into the entire world. Companies need to present their Chinese characteristics to the world. Chinese characters are used in the logo design, which presents a unique Chinese cultural heritage. As a representation of Chinese characteristics, Chinese characters have their profound meaning and expressive power. It provides a vast space for the design of logo image. Chinese character is mainly characterized by the interpenetration between pictographic forms and strokes. Pictographic Chinese characters can almost be used as design works without further design. These ancient Chinese characters have the characteristics of expressing some special meanings and are more visual and symbolic. Recently, many outstanding logo design works have appeared, such as the Beijing Olympics logo, the Shanghai World Expo logo, the Bank of China logo, and the Hangzhou City logo. Artistic Chinese character is a way to visualize the beautiful design. The

application of artistic Chinese characters in the design of logo image not only is the development of a form of expression, but also the use of the cultural attributes and cultural identity of Chinese characters to create design works with national cultural characteristics.

Design of artistic Chinese character refers to the activities to make an overall and careful arrangement of the text according to the rules of visual design. It is to use decorative techniques to beautify the writing art of the text. In the era of multimedia, the internet has become the main carrier of information dissemination, innovation. Artistic design are the mainstream of social development, and characters can be no exception. In the environment of high-speed information, it is necessary to make character design unique and capable of attracting people's attention. The traditional font has been difficult to meet the needs of the times. Around the 1920s, young international students absorbed art and design from Japan, Europe, and the United States and then introduced the design theory to enrich the performance of Chinese character. Modern art characters use the structure of Chinese characters and stippling as elements. Through careful thought and artistic organization, the characters are expressed in the image of beauty, so that they conform to the specific environment. This has transformed Chinese characters from the traditional line structure to the volume structure of gage blocks characterized by points, lines, and facets. At the same time, it has long relied on perceptual knowledge to form a new concept of Chinese character design. With the rapid development of computer technology, various design software applications arose. This graphic image design software provided a fast and accurate technical guarantee for font design, which resulted in computer-aided design-based font design. At the same time, with the rise of artificial intelligence technology, more and more researchers have developed different algorithms and models for font design and font recognition. For example, Plamondon and Srihari [1] examined the positional relationship of strokes of Chinese characters as an attribute relationship map, and then projected the pen segment onto the coordinate axis to realize the tailoring of writing information. A matching relationship between template characters and handwriting can be used to achieve the purpose of handwritten artistic characters. Chen et al. [2] classified the strokes of Chinese characters and then matched them with Chinese template characters. It provides a technique for error feedback and improvement guidance. Chung et al. [3] used a dynamic programming algorithm to perform glyph matching and used the compatibility between pen segments to iteratively adjust the similarity of pen segments to obtain the maximum matching result. The glyph matching algorithm proposed by Liu et al. [4] presented good matching accuracy and computational efficiency. Zhang et al. [5] developed an artistic character font recognition system based on the relative center of glyphs. By clustering the differences of various stroke parameters, it achieves the purpose of locating key writing defects in handwritten Chinese characters. Xiao et al. [6] proposed a method for designing and recognizing artistic fonts based on a convolutional neural network model. This method can quickly recognize large-scale handwritten Chinese characters and artistic fonts. Zhang et al. [7] proposed a method for calculating the visual center of gravity of Chinese character glyphs based on neural networks. The results indicate the visual center of gravity of Chinese characters depends on the subjective experience of people. It can be widely used in the extraction of Chinese character features, the design and optimization of Chinese character structures. Yang et al. [8] adopted a category-aware paradigm to compare artistic fonts expressed in simplified Chinese characters with expressed in traditional characters. The results show that simplified Chinese characters have a higher visual recognition rate in character reading than traditional Chinese. This is because the traditional Chinese character library production technology requires a large number of manual operations on the word formation results. Lin et al. [9] proposed a method of using the attribute characteristics of Chinese characters to realize the quality evaluation of the word formation results. This method uses image processing technology to extract the attributes and to quantify the evaluation criteria of Chinese character quality. An improved three-layer back propagation neural network is used in their work to establish an evaluation model of Chinese character quality. Based on this, the manual investment in the process of making the font is reduced. Sun et al. [10] used back propagation neural network to train 22 global statistical features and 10 structural layout features of Chinese characters to build an aesthetic evaluation model. They also analyzed the importance of these characteristic parameters. Wang et al. [11] proposed an aggregation network method for Chinese

character decoding. Experimental results show that the method can effectively recognize very fuzzy strokes with a small number of supporting samples while maintaining high performance on visible characters. Zhang et al. [12] used a deep convolutional neural network to recognize similar handwritten Chinese characters with an accuracy rate of 98%. Therefore, this method can be used to realize the design of artistic font. By comparing with existing databases, different fonts can be designed.

The above research mainly focused on the use of new algorithms and technologies to realize the recognition of Chinese characters, as well as the simulation and optimization of the structure of Chinese characters. It lacked the design of artistic fonts, especially the use of computer's computing advantages. In the publishing material, the title of the article often needs to use individual shaped glyphs to activate the layout or highlight the theme. In advertising, trademark, and software cover design, some aesthetic and artistic Chinese characters are used to enhance the decorative effect. Artistic Chinese characters have great practical application value. Therefore, this paper proposes a computer-aided design method for the design of artistic Chinese characters. This method uses the graphic characteristics of dot matrix Chinese characters to transform them into a dynamic soft character library. The dynamic soft character library technology is different from the glyph font technology. It can significantly save hardware resources. Furthermore, the system uses the Chinese drop-down menu as the user interface, which is flexible and convenient to use and has excellent practical application value.

2   RESEARCH METHOD

Chinese characters are hieroglyphs. The geometric deformation of Chinese character structure has significant modeling value, which is an essential content of artistic Chinese character design. In computer-aided design, based on dot matrix Chinese characters, various artistic characters are generated through enlargement and geometric deformation, such as rectangular fonts with different aspect ratios, italic fonts, various directions, various gradient trapezoidal fonts, Round fonts of various radii, etc. The core problem of artistic Chinese characters is to map the 2D Chinese character glyph dot matrix extracted from the Chinese character model library to the target geometric array. Different geometric configurations use different mapping functions. It mainly includes the Chinese character icon processing model, geometric configuration processing mathematical model, modeling decoration processing mathematical model, and font geometric size processing mathematical model.

2.1   Chinese Character Processing Model

The shape pixels in different positions of the glyph play a different role in recording and transmitting information. The information contained in them is also different. The functions of the pixels in the glyph configuration are list as follows: a) the characterization of the recording strokes; b) participation in the modeling and decoration of strokes; c) forming the geometric size of the strokes. The main point of the presentation is to separate the information elements in the original glyph that need to be retained and discarded. For example, the original glyph's decorative information can be discarded. The logical conditions for the new glyph's modeling can be prepared based on the retained stroke logical structure information. The decorative pixel on the right end of the Song script can be identified, and it can be retained and discarded according to the needs of deformation. You can add pixels in the middle of the stroke to change the length of the stroke, the dot matrix of words. The 16 x 16 dot matrix is the simplest Chinese glyph dot matrix. It basically represents all Chinese glyphs, but it looks rough. The characters in the 24 x 24 dot matrix Chinese characters are thin and thick. They can show the stroke of the pen. Therefore, this work uses the 24 x 24 dot matrix as a prototype for the design of artistic Chinese characters.

The geometric deformation of Chinese characters is to expand the original 24 X 24 glyph dot matrix proportionally to larger rectangular, trapezoidal, circular and other areas. To determine whether each point in the target area is colored, it is necessary to map each point in the target area to a specific point in the original lattice and map the coloring situation of the specific point to

the target point. Establishment of the relationship between each point of the target area and the points of the source area has the following two steps. First, the target area is compressed vertically so that each line of the target area corresponds to a line in the source area. Each target line is compressed horizontally to make the target of each point in the array corresponding to a point in the source display. The essence of this process is proportional compression. The most direct algorithm of proportional compression is to multiply the coordinates of each point in the target lattice by a scale factor. It calculates the coordinates of the corresponding points in the original lattice.

The national standard stipulates that each Chinese character has a specific area and bit in the font. It implies that there is an area and location code for each character in the font database. The location code helps the designer to know the position and the content of the Chinese character in the font. In addition, the information is also related to font mode, graphics mode. It is useful to display the Chinese character by drawing points.

The area code of a Chinese character is C1 and the bit code is C2. If a 24 X 24 dot matrix Chinese character are used as a record, knowing the position of the Chinese character in the font is equivalent to the record number No of the Chinese character. As shown in Eq. (1). After the record number (*NO.*) of the Chinese character is obtained, the offset position (*S*)of each byte of the font in the font of the Chinese character can be obtained by multiplying 72 by formula (2).

$$No. = (C1-1)*94 + C2-1 \tag{1}$$

$$S = No.*72 \tag{2}$$

2.2   Mathematical Model for Geometric Configuration Processing

After the Chinese character information is read from the character library, the Chinese character information needs to be processed by using the geometric configuration processing model. The geometric processing model determines the layout of the new glyph skeleton structure, which is realized by array mapping processing technology. The original glyph icon array is re-formed according to the trajectories of various curves in the plane, or according to the behavior of solid entities in the plane in the plane. Sometimes, in order to feel a spatial layout, you need to use various similarity, scaling calculations, and projection processing. Different array geometries use different array mapping functions. The original glyph icon array can be geometrically configured simultaneously according to a variety of curves or surfaces. The various curve and surface forming processes need to be carefully coordinated to ensure that the new glyph icon array generated by the configuration maintains the original glyph. The stroke logic is logical, and the joints between the curves and surfaces should naturally have no traces.

Digital Differential Analyzer (DDA) is a well-known algorithm in computer graphics. It can map the Chinese character glyph dot matrix to the new glyph dot matrix. This algorithm not only has excellent efficiency but also has a wide range of applications. A set of virtual grid lines is constructed by the pixel centers of each row and column. First, the intersection point of the straight line and each vertical grid line is calculated in the order of the straight line from the start point to the end point. Next, the pixel closest to this intersection point in the column of pixels is determine according to the sign of the error term. When using the linear equation $y = kx + b$ to determine the position of a pixel, the coordinates of the y point are obtained according to the coordinates of the x point. This will use multiplication calculations and increase the computational complexity. The DDA line drawing algorithm converts the multiplication operation to the addition operation through the incremental thinking. Thus, the efficiency and the accuracy will be improved, and the error will be reduced. In an iterative algorithm, the x and y values of each step are obtained by adding the value of the previous step and an increment.

For a straight line with a small inclination of the starting point $P_0(x_0, y_0)$ and the end point $P_n(x_n, y_n)$, the slope of the straight line is determined by Eq.(3):

$$k = \frac{\Delta y}{\Delta x} = \frac{y_n - y_0}{x_n - x_0} \tag{3}$$

The linear equation is thus obtained:

$$y_i = kx_i + b \tag{4}$$

When $k < 1$, assuming x_0 is known, each time it advances one pixel along the x-axis direction (with a step size of 1), the corresponding y_0 value can be calculated. Because the coordinates of the pixels are integers, the calculated y_0 value must be rounded. The rounding method is to add 0.5 and then round it. The specific increment formula is derived as follows. Its meaning is that the current y_{i+1} value is equal to the previous step y_i value plus the slope k, and k is called the increment.

$$y_{i+1} = kx_{i+1} = k(x_i + 1) + b = kx_i + k + b = y_i + k \tag{5}$$

When $k > 1$, assuming that y_0 is known, each time it advances one pixel along the y-axis direction (with a step size of 1), the corresponding x_0 value can be calculated. Because the coordinates of the pixel are integers, the calculated x_0 value must be rounded. The rounding method is to add 0.5 and then round it. The specific increment formula is derived as follows. Its meaning is that the current x_{i+1} value is equal to the previous step x_i value minus the slope $\frac{1}{k}$.

$$x_i = \frac{y_{i+1} - b}{k} = \frac{y_i + 1 - b}{k} = \frac{y_i - b}{k} - \frac{1}{k} = x_i - \frac{1}{k} \tag{6}$$

A common feature of the geometric deformation of Chinese characters is that an ordinal sequence with a significant number of terms is proportionally compressed and mapped to another homologous sequence with a lower number of terms. If the former is regarded as a sequence of abscissa x values 0, 1, ..., (n-1), the latter can be regarded as a sequence of ordinate y values 0,1, ..., 24. The mapping of two series of the coordinates can be regarded as the coordinate values $(x, \text{int}(kx_i))$ of n points on $y = kx + b$. The process of proportional compression is similar to the process of drawing a straight line. Thus, the DDA algorithm can be directly applied to realize the compression mapping of two sequences. The above is just a simple acceptance of the DDS straight line algorithm. The specific DDA straight line algorithm diagram is shown in Figure 1.

2.3 Mathematical Model for Font Geometry Processing

The mathematical model of glyph geometric size processing supports various glyphs with different sizes and different aspect ratios for the same shape. This process uses mathematical methods such as proportionality and similar geometry. Three basic Chinese characters are transformed into the enlargement, rotation and tilt of Chinese characters.

Amplification

$$\begin{cases} X_1 = A * X_0 \\ Y_1 = A * Y_0 \end{cases} \tag{7}$$
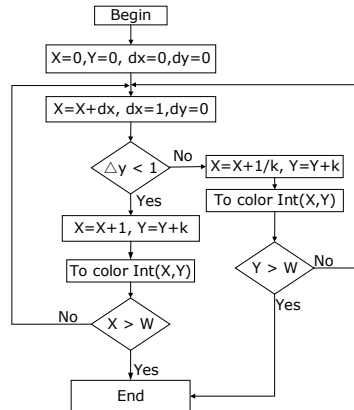
Figure 1: DDA straight line algorithm for Chinese arts and crafts.

In the formula, A is the magnification, and (X_0, Y_0) and (X_1, Y_1) are the pixel coordinates of the font before and after the enlargement, respectively.

Spin

$$\begin{cases} X_1 = X_0 + Y_0 \tan\theta \\ Y_1 = Y_0 \end{cases} \tag{8}$$

In the formula, θ is the inclination angle of Chinese characters.

Slope

$$\begin{cases} X_1 = X_0 \cos\alpha - Y_0 \sin\alpha \\ Y_1 = X_0 \sin\alpha + Y_0 \cos\alpha \end{cases} \tag{9}$$

In the formula, α is the counterclockwise rotation angle of Chinese characters.

2.4   Modelling Decoration Processing Model

The overall decoration of the glyphs and the stroke decoration are different in the models and algorithms used in computer design. The overall decoration of artistic Chinese characters refers to the deformation of the overall structure of the glyph, such as making it hollow, giving it an edge or making it three-dimensional. Different mathematical models are used for different overall decorative purposes. However, the mathematical processing method for the overall decoration of certain glyphs also has a common aspect. For example, the overall decoration, such as hollow, double shadow, and hemming are all based on the original shape. The decorative part is derived from the original shape. The two are combined to complete the decorative design.

The decorative design of glyphs is an area where art ingenuity is used. There are various methods of modeling and decoration. For example, on the basis of the geometric deformation of the cuboid, a variety of decorative changes, and a variety of wind body shapes can be obtained. The common principle of different styles of glyph design is to strive to express a sense of dynamics and speed. The only difference is the change of decorative details. The model needs to be enhanced and perfected in practice. In addition, more decoration processing model should be proposed to design the Chinese characters.

Various glyphs can be deduced and changed from mathematical theories. Practice has proved that many glyphs are not beautiful and impatient. Art creation is image thinking. The glyphs inferred from logical thinking such as mathematical models need to be optimized by an artist. Here, visual aesthetic rules such as the golden section are used. In computer processing, a processing method similar to an expert system is used. For non-optimized parameters, the design system treats them as illegal parameters. The parameters determined by the artist's optimization are listed in the design selection range, and the computer automatically converts the parameters selected by the designer to the closest optimization number.

3   COMPUTER AIDED DESIGN OF CHINESE CHARACTERS

3.1   The Logic Flow of Font Design
Based on the graphic characteristics of dot matrix Chinese characters, transformation and mapping for the Chinese characters can be performed according to the principles of graphic processing. A computer-aided design system of artistic Chinese characters is designed, which can realize the design of flat fonts, space fonts and three-dimensional fonts. The font design logic flow chart is shown in Figure 2.
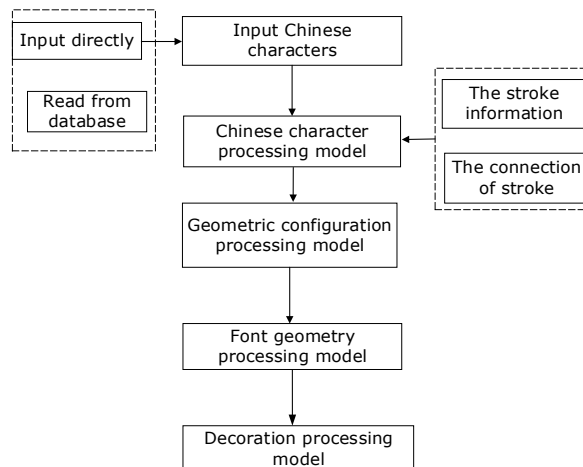
Figure 2: Computer-aided design framework of Chinese characters.

3.2   Chinese Character Design Software
The following is a brief introduction to the system proposed in this work. The computer-aided design system of artistic Chinese characters mainly includes system interface design, function design and technology realization module. There are three buttons in the middle of the system interface, i.e., flat font design, space font design and three-dimensional font design. If the designer clicks any buttons on the interface, the system will enter the design interface of the corresponding font. Next, the designer selects the desired font and the results of design will be presented in the result area. If you need to return to the system interface, click the back button in the lower right corner. This software can design flat font, space font and three-dimensional font, as shown in Figure 3.

The program for the system interface program is shown in Figure 5. It could make the system adjusting the size of the software window and ensuring that the window is centered relative to the screen. Thus, the window can automatically adapt to the width of the user's computer screen. The background image of each interface can change as the interface size changes.
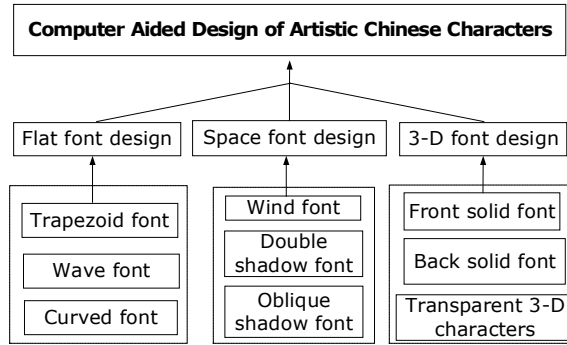
Figure 3: The function of the system of artistic Chinese characters design.

**Figure 4:** The menu page for the proposed system.

Figure 5: The program code for the system menu page.

After entering the software design interface shown in Figure 4, the designer clicks the different buttons to design the corresponding font. This work takes spatial font design as an example. The space font mainly includes reflection characters, superimposed characters, group photograph characters, oblique projection characters and style characters. The following mainly introduces superimposed characters and style characters. Superimposed characters can be obtained by using two layers of characters with the same size but different decorative effects to be displayed adjacent to each other. Superimposed characters are composed of foreground characters and background characters. The foreground characters are predominant shapes, which can be either black or white, and the background characters are auxiliary shapes. Generally, they are contrasted with different colors. The superimposed character expresses the sense of spatial distance and artistic beauty of the character through the positional shift between the front and back scenes and the contrast between light and dark. In this software, after inputting the Chinese characters that need to be designed, the designer selects the superimposed font and runs the program to get the results, as shown in Figure 6. The system can be used to design wind font. The wind font is based on the italic font, with wind line decoration in some positions. The length of the wind line is short and consistent with the font. In the font selection column, select the style, and you can get the results shown in Figure 6.
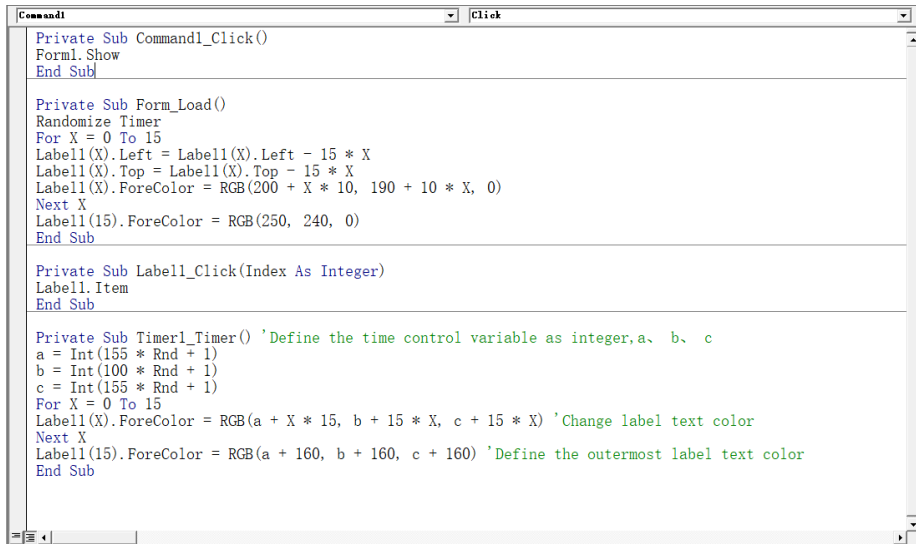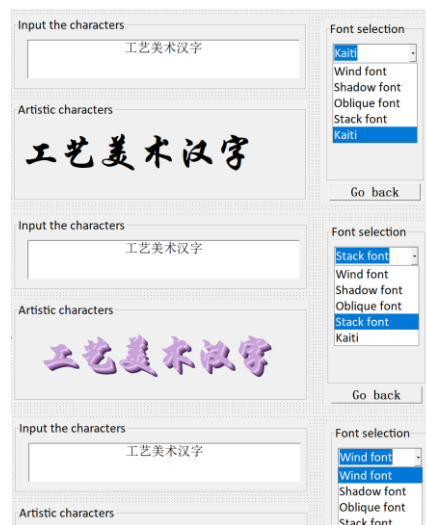

Figure 6: Superimposed font design results.

The main program code for the design of superimposed characters and styles is shown in Figure 7. The specific idea is to first copy the label control and then paste it 15 times at the current position to get a one-dimensional array, that is, Label1 (0) --- Label (15); then all objects, namely Label1 (0)-Label (15) Select all of them and align them left and top to make these objects coincide. Finally, the position parameters of these objects can be adjusted to obtain the double shadow character and the style character respectively.

4   CONCLUSIONS

Chinese characters are the only long-lasting two-dimensional graphic characters among the three elephant-shaped characters in the world. The meaning of Chinese characters can be reflected more vividly and profoundly through art deformation. It inspires people's deep understanding of the meaning of the characters and enriches the aesthetic connotation of Chinese characters. Furthermore, it could increase people's interest in appreciation. The computer design method for

the artistic Chinese characters proposed in this paper is a dynamic soft character library obtained by transforming the dot matrix Chinese characters and processing them.

```
Command1                          ▼  Click                                    ▼
Private Sub Command1_Click()
Form1.Show
End Sub

Private Sub Form_Load()
Randomize Timer
For X = 0 To 15
Label1(X).Left = Label1(X).Left - 15 * X
Label1(X).Top = Label1(X).Top - 15 * X
Label1(X).ForeColor = RGB(200 + X * 10, 190 + 10 * X, 0)
Next X
Label1(15).ForeColor = RGB(250, 240, 0)
End Sub

Private Sub Label1_Click(Index As Integer)
Label1.Item
End Sub

Private Sub Timer1_Timer() 'Define the time control variable as integer,a、 b、 c
a = Int(155 * Rnd + 1)
b = Int(100 * Rnd + 1)
c = Int(155 * Rnd + 1)
For X = 0 To 15
Label1(X).ForeColor = RGB(a + X * 15, b + 15 * X, c + 15 * X) 'Change label text color
Next X
Label1(15).ForeColor = RGB(a + 160, b + 160, c + 160) 'Define the outermost label text color
End Sub
```

Figure 7: Font design program.

It requires less storage capacity, which can greatly save hardware resources, and the system uses Chinese menus as the user interface is flexible and convenient to use and has great practical application value. Computer-aided design of artistic Chinese characters is the application of computer Chinese character information technology in the field of Chinese character processing. It has broad application prospects in newspapers, magazines, book cover design, product packaging, advertising sign design and other fields.

Yongqiang Guo, https://orcid.org/0000-0002-1129-9752

REFERENCES

[1]   Plamondon, R.; Srihari, S.-N.: On-line and off-line handwriting recognition: a comprehensive survey, IEEE Transactions on Pattern Analysis and Machine Intelligence, 22(1), 2000, 63-84. https://doi.org/10.1109/34.824821
[2]   Chen, H.-C.; d'Arcais, G.-B.-F.; Cheung, S.-L.: Orthographic and phonological activation in recognizing Chinese characters, Psychological Research, 58(2), 1995, 144-153. https://doi.org/10.1007/BF00571102
[3]   Chung, K.-L.; Li, W.; Li, Y.; Liu R.; Zhang, P.: Chinese character-shaped artistic patch antenna, IEEE Antennas and Wireless Propagation Letters 18(8), 2019, 1542-1546. https://doi.org/10.1109/LAWP.2019.2920697
[4]   Liu, N.; Yu, R.; Zhang, Y.: Effects of font size, stroke width, and character complexity on the legibility of Chinese characters, Human Factors and Ergonomics in Manufacturing & Service Industries, 26(3), 2016, 381-392. https://doi.org/10.1002/hfm.2066
[5]   Zhang, J.; Bi, H.; Chen, Y.; Wang M.; Han L.; Cai, L.: Smart handwriting: handwritten Chinese character recognition with wmartwatch, IEEE Internet of Things Journal, 7(2), 2019, 960-970. https://doi.org/10.1109/JIOT.2019.2947448
[6]   Xiao, X.; Jin, L.; Yang, Y.; Yang, W.; Sun, J.; Chang, T.: Building fast and compact convolutional neural networks for offline handwritten Chinese character recognition, Pattern Recognition, 72, 2017, 72-81. https://doi.org/10.1016/j.patcog.2017.06.032

[7]   Zhang, X.-Y.; Yin, F.; Zhang, Y.-M.; Liu, C.-L.; Bengio, Y.: Drawing and recognizing Chinese characters with recurrent neural network, IEEE transactions on Pattern Analysis and Machine Intelligence, 40(4), 2017, 849-862. https://doi.org/10.1109/TPAMI.2017.2695539
[8]   Yang, R.; Wang, W.-S.-Y.: Categorical perception of Chinese characters by simplified and traditional Chinese readers, Reading and Writing, 31(5), 2018, 1133-1154. https://doi.org/10.1007/s11145-018-9832-y
[9]   Lin, D.; Lin, F.; Lv, Y.; Cai, F.; Cao, D.: Chinese character CAPTCHA recognition and performance estimation via deep neural network, Neurocomputing, 288, 2018, 11-19. https://doi.org/10.1016/j.neucom.2017.02.105
[10]   Qu, X.; Wang W.; Lu, K.; Zhou, J.: Data augmentation and directional feature maps extraction for in-air handwritten Chinese character recognition based on convolutional neural network, Pattern Recognition Letters, 111, 2018, 9-15. https://doi.org/10.1016/j.patrec.2018.04.001
[11]   Wang, T.; Xie, Z.; Li, Z.; Jin, L.; Chen, X.: Radical aggregation network for few-shot offline handwritten Chinese character recognition, Pattern Recognition Letters, 125, 2019, 821-827. https://doi.org/10.1016/j.patrec.2019.08.005
[12]   Zhang, S.; Jin, L.; Lin, L.: Discovering similar Chinese characters in online handwriting with deep convolutional neural networks, International Journal on Document Analysis and Recognition, 19(3), 2016, 237-252. https://doi.org/10.1007/s10032-016-0268-0