Image iterative method for handwritten Chinese character recognition

Wanbo Yu1st,a, Yaosheng Li2nd*, Hongwei Peng3rd, Li Zhang4th
School of Information Engineering, Dalian University, Dalian, China
ayuwanbo@dlu.edu.cn
*Corresponding author: 774526687@qq.com

Abstract—Although accuracy and calculation time of handwritten Chinese character recognition have been greatly improved, it has not yet reached the practical application standard. Recently, iterative methods are used to recognize face images and good results are obtained. Therefore, image recognition is improved based on this idea. In this paper, linear combination of trigonometric functions is used as auxiliary functions and image to construct discrete dynamic system. By adding bevel and shift to construct font surfaces and so on, the system structure is improved to solve problem of system convergence caused by large area flatness of handwritten Chinese character images, and good recognition effect is achieved. Preliminary experiments (for example, extracting 20 Chinese characters written by 9 people in the dataset) are carried out, and recognition rate can reach 100% when all of them are trained, and recognition rate can reach 76.7% when each Chinese character is trained to 3 pieces; in addition, experiments were conducted on handwritten Chinese character sets changing from different angles, and the recognition rate reached 80%, which was compared with other algorithms to verify the feasibility of handwritten Chinese character recognition algorithm based on chaotic iterative trajectory characteristics of images.

1. INTRODUCTION
Image recognition technology is widely used and has become a research hotspot in recent years [1-3]. Handwritten recognition of various languages, as a special kind of image recognition, is under study [4-7]. Due to the characteristics of Chinese characters, there are many papers on handwritten recognition of Chinese characters, Shao, etc. character image restoration method is proposed for unconstrained handwritten Chinese character recognition[8]; Ren, etc. present a new hybrid-parameter RNN which consists of two virtual unidirectional recurrent neural networks, accumulate the feature vectors from different layers to obtain the output of the RNN system[9]. Zhang, etc. recent HCCR methods based on deep learning are compared and new benchmarks for online and offline HCCR are set[10]. Wang, etc. The parameters of writer-adaptive layers are jointly optimized with other network parameters in the training stage, while a multiple-pass decoding strategy is adopted to learn the writer code and generate recognition results. Validated on the ICDAR 2013 competition of CASIA-HWDB database, the more compact WCNN-PHMM of a 7360-class vocabulary can achieve a relative character error rate (CER) reduction of 16.6% over the conventional CNN-HMM without considering language modeling[11]. Based on the iterative theory, experiment will take the iterative method as the core method, using the characteristics of the iterative function system to construct the relevant dynamic system, generate the iterative sequences, analyze and study these iterative sequences, obtain certain rules from them, and identify and explore them as the features of handwritten images.
Chinese character database was used as the experimental data set for identification[12], and MATLAB was used to realize the experimental simulation.

2. CONSTRUCTION AND ANALYSIS OF IMAGE ITERATIVE DYNAMICAL SYSTEM

2.1. Image library and its read
According to the data characteristics of HCL2000 Chinese character database, it can be known that HCL2000 Chinese character data images are organized and stored in file form according to the writer. Each HCL file contains a 512-byte header that records information about the file. Each handwritten Chinese character is stored in the order of location code, and each Chinese character image is a binary dot matrix of 64*64, which is stored in bits during the storage process and compressed into 512 bytes.

Therefore, when we obtain the image data, we need to extract the Chinese character data in the HCL file and restore it to a lattice of 64*64. Here, according to the HCL file reading method given by the pattern recognition laboratory of Beijing university of posts and telecommunications, it is implemented by MATLAB to read and take out the specified handwritten Chinese character images. The gray value of each image is about 40-60. Figure 1 and figure 2 below show the first 20 Chinese characters written by the first and second person in the data set.

![Figure 1. Images of the first 20 Chinese characters written by the first person in datasets](image1)

![Figure 2. Images of the first 20 Chinese characters written by the second person in datasets](image2)

Since obtained image is a matrix of 64*64, at the beginning, we tried to directly calculate matrix correlation coefficient, and the results could not well express the correlation between the two images. Therefore, the image matrix data cannot be directly used to calculate the correlation. Next, we will try to use the iterative function system to extract and identify the features of handwritten Chinese character images.

2.2. Dynamical structure
In this paper, the constructed dynamic system is shown in formula (1) below:

$$\begin{align*}
z_i(u,v) &= n \times \sin\left( k \times \left( \frac{u}{n+1} \right)^2 \right) + 1
& \quad \times \sin\left( k \times \left( \frac{v}{n+1} \right)^2 \right) + 1
& \quad \times \sin\left( 2 \times \left( \frac{u}{n+1} \right)^2 \right) + 1
& \quad \times \sin\left( 2 \times \left( \frac{v}{n+1} \right)^2 \right) + 1
\end{align*}$$

According to the size of Chinese characters and the amount of information expressed, n is 63, and k determines the period of the system, which is determined according to the specific problem. The algorithm is designed as follows.

**Algorithm 1** Dynamic system construction and trajectory generation
1) Open the data set file and read the handwritten Chinese character data;
2) Extract the bit data of handwritten Chinese characters into a matrix of 64*64 size, stored in a two-dimensional array $E_{64 \times 64}$;
3) Determine the initial value set \( C \) of iteration and iteration times \( m \). Set \( C \) is composed of \( p \) positive integer point pairs \((u, v)\), with \( u \) and \( v \) between 1 and 64.

4) Carry out iterative operation, substituting each \((u, v)\) into formula (1), and calculating \((z_1, z_2)\), perform an assignment operation \( T(z_1, z_2) \leftarrow 1; \)

5) Implement iteration, that is, perform an assignment operation \( u \leftarrow z_1, v \leftarrow z_2; \)

6) Perform 4) and 5) \( m \) times;

7) Save and output iteration trajectory matrix \( T; \)

Experimental research and theoretical analysis found that:
- Because system shown in formula (1) has poor chaotic characteristics and is easy to converge, the initial value \((u, v)\) is relatively small, and the sequence points obtained when the number of iterations is large (\( m \) is large) are relatively small, the effect is not good, and a better set of iteration trajectories cannot be obtained.
- Take advantage of all points to participate in the iteration, each iteration 1 to 2 times (\( m = 1, 2 \)), analyzed their experimental data, the same Chinese characters has the highest correlation coefficient can reach 0.3, correlation coefficient of different Chinese characters also can keep mostly in 0.15 the following (partial result anomaly), can be a preliminary prove the feasibility of using the iterative method is used to identify the Chinese characters.

Next, considering some relevant processing of the target image in order to get better experimental data.

3. HANDWRITTEN CHINESE CHARACTER IMAGE RECOGNITION

3.1. Image processing

3.1.1. Add a bevel to the Handwritten Chinese character image
According to the size of image, a bevel matrix of the same size is initialized and added to the target image matrix to make it overall inclined and reduce the pixel difference of the font edge. Then, the processed image matrix is used for iterative calculus to obtain the iterative sequence and calculate the correlation coefficient. The experimental steps are as follows:

![Experimental procedure flow chart](image)

3.1.2. Stretch and increase the image
Next, trying to stretch the whole target image and increase the height of its font (the idea comes from engraving). The specific operation is as follows:

The handwritten Chinese character image is operated by pixel displacement. Through the loop, the original image pixels in turn to the left, down, right, up to displacement of the image after every displacement superposition, which broadens image font and make it up, then after stack size is 64 * 64 image magnification is 256 * 256 and to the normalized processing of image matrix, and keep its pixel values between 1 and 255. Finally, the processed image and the trigonometric function are used to
construct the dynamic system and carry out the next experimental operation.

3.2. Identification and optimization
Modifying the parameters, modifying the dynamic system, trying to use multiple features to identify.

3.2.1. Integrated feature extraction of multiple Chinese characters
In order to facilitate experimental operation, obtained the same Chinese character written by many people and carried out the iterative experiment respectively. The sequence of each iteration was integrated as the comprehensive feature of the character, then the correlation coefficient was calculated with the iterative sequence of the target image to judge its correlation. Preliminary experiments show that correlation coefficient of the same character is higher than that of a single character.

3.2.2. Modify parameters
On the basis of the above operation, the image font was adjusted several times to expand the superposition scale, and the experimental results were recorded successively, finally an optimal scale was obtained. On this basis, the experiment was carried out by adjusting the number of points involved in the iteration of the image matrix, and experimental effect was best when one point was selected from six points apart from the image after several times of comparison. The kk value in the iterative formula was changed several times for experiments. Finally, it was found that when kk=3.9, the correlation coefficient of the same word could reach up to about 0.48.

3.2.3. Establishment of feature data set and multi-feature comprehensive recognition
As mentioned above, multiple iterative sequences of the same Chinese characters are used for correlation detection. On the basis of this idea, features are extracted by using multiple groups of parameters at the same time to build feature data sets. Then, relevant calculations are made for these different feature data, and correlation coefficients are obtained by combining them. Here, 5 to 8 groups of parameters with good experimental effect are selected for experimental exploration. Specific operations are as follows:

• 1. Create a sample feature data set file to save the sample feature data;
• 2. Multiple groups of parameters were used for experimental operation, and obtained feature data were successively stored in the sample data set;
• 3. Read the data set file, obtain the feature data, do some calculation and processing, and get a comprehensive feature matrix;
• 4. Obtain the target image and obtain the target feature data by the same method as above;
• 5. Calculate correlation coefficient between sample characteristic data and target characteristic data, and draw the experimental conclusion.

The correlation coefficient of the same Chinese character can reach up to about 0.75. In the above experiment, only the same Chinese character written by ten people was used as the sample for the experiment. Next, considering expanding the sample size to see the experiment effect.

3.3. Identification effect and analysis
According to the above algorithm, the average feature matrix of each Chinese character in the sample is calculated and stored in the order of the Chinese characters. Then correlation coefficient is calculated by using the characteristics of the target Chinese characters and the average characteristics of the sample Chinese characters. To determine whether the sample position with the largest correlation coefficient corresponding to each target Chinese character is the same as the position of the Chinese character arrangement. The same indicates successful identification.

First of all, makes a horizontal comparison and uses multiple Chinese characters written by one person to carry out the experiment. The results are shown in Table 1 below:
Then the longitudinal comparison, using multiple Chinese characters written by different people to experiment. For example, 20 Chinese characters written by 9 people were extracted, a total of 180 Chinese images were collected, and 5 images were trained for each character, 138 Chinese characters could be recognized, and recognition rate was 76.7%. If 9 pieces of each Chinese character are trained (i.e. all of them are trained), 180 pieces can be recognized and recognition rate is 100%. In order to ensure accuracy of experimental results, we continued to expand the sample data for the experiment. The results are shown in Table 2.

| Sample data                        | number of samples | Training situation | Identification results | Recognition rate |
|-----------------------------------|-------------------|--------------------|------------------------|------------------|
| 300 characters written by 9 people | 2700              | All the training   | 2700                   | 100%             |
| 500 characters written by 9 people | 4500              | All the training   | 4500                   | 100%             |
| 500 characters written by 20 people| 10000             | All the training   | 8917                   | 89.2%            |

These experimental results show that the iterative method for extracting the features of handwritten Chinese characters is feasible, has achieved good experimental results, and has a certain value for use.

4. SUMMARY
At present, the commonly used offline handwritten Chinese character recognition is mainly based on deep learning technology. When acquiring sample data, these methods need a lot of training to achieve a satisfactory degree. The system structure is complex and the operation cost is high. The method of feature extraction and recognition proposed in this paper, by iteratively constructing feature matrix to obtain sample data, reduces the complexity and operation cost of the system structure to some extent, and improves the experimental efficiency.

ACKNOWLEDGMENTS
Thank you for the support of the Dalian University Graduate Education and Teaching Reform Fund (2018)
REFERENCES

[1] Xiao-bo Zhang, Xiao-guang Ge, et al. Application of image recognition technology in census of national traditional Chinese medicine resources[J]. China journal of Chinese materia medica. 2017, 42(22):4266-4270.

[2] Zheng Han, Bin Su, Yan-ge Li, Yang-fan Ma, Wei-dong Wang, Guang-qi Chen. An enhanced image binarization method incorporating with Monte-Carlo simulation[J]. Journal of Central South University, 2019,26(6).

[3] Tian-wei Wang, Ze-cheng Xie, Zhe Li, Lian-wen Jin, Xiang-le Chen. Radical aggregation network for few-shot offline handwritten Chinese character recognition[J]. Pattern recognition Letters, 2019, 125(8):821-827.

[4] He-ming Huang, Fei-peng Da. A dictionary learning and KPCA-based feature extraction method for off-line handwritten Tibetan character recognition[J]. Optik - International Journal for Light and Electron Optics, 2015, 126(23):3795-3800.

[5] Showmik Bhowmik, Samir Malakar, Ram Sarkar, Subhadip Basu, Mahantapas Kundu, Mita Nasipuri. Off-line Bangla handwritten word recognition: a holistic approach[J]. Neural Computing and Applications, 2019,31(10):5783-5798.

[6] Munish Kumar, M. K. Jindal, R. K. Sharma, Simpel Rani Jindal. Character and numeral recognition for non-Indic and Indic scripts: a survey[J]. Artificial Intelligence Review, 2019,52(4):2235-2261.

[7] Prateek Keserwani, Tofik Ali, Partha Pratim Roy. Handwritten Bangla character and numeral recognition using convolutional neural network for low-memory GPU[J]. International Journal of Machine Learning and Cybernetics, 2019,10(12):3485-3497.

[8] Yun-xue Shao, Chun-heng Wang, Bai-hua Xiao. A character image restoration method for unconstrained handwritten Chinese character recognition[J]. International Journal on Document Analysis and Recognition, 2015,18(1):73-86.

[9] [9] Hai-qing Ren, Wei-qiang Wang, Xi-wen Qu, Yuan-qiang Cai. A New Hybrid-parameter Recurrent Neural Network for Online Handwritten Chinese Character Recognition[J]. Pattern Recognition Letters, 2019,128:400-406.

[10] Xu-yao Zhang, Yoshua Bengio, Cheng-lin Liu. Online and offline handwritten Chinese character recognition: A comprehensive study and new benchmark[J]. Pattern Recognition, 2017, 61:348-360.

[11] Zi-rui Wang, Jun Du, Jia-ming Wang. Writer-Aware CNN for Parsimonious HMM-Based Offline Handwritten Chinese Text Recognition[J]. Pattern Recognition, 2019.

[12] Hong-gang Zhang, et al. HCL2000 - A Large-scale Handwritten Chinese Character Database for Handwritten Character Recognition. 2009 10th International Conference on Document Analysis and Recognition IEEE Computer Society, 2009.

[13] Ting-ting Dai, Bin Sun. Novel Features for Character Extraction of Historical Chinese Seal Images[J]. Sensing and Imaging, 2019,20(1):1-17.