Research on Handwritten Chinese Character Recognition Based on BP Neural Network

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1. Introduction

Today, with the increasing popularity of artificial intelligence, artificial intelligence has been gradually integrated into our lives, penetrating into various fields and leading the development of new technologies. As an important part of artificial intelligence, artificial neural network has made great progress in recent years. Artificial neural network has been widely concerned because of its strong function of searching for optimal solution by associative storage of things and strong self-learning ability. The multilayer feedforward BP (Back Propagation) neural network trained by error back propagation algorithm has good nonlinear mapping ability and good flexible network structure. At present, the research on BP neural network is relatively mature, so it is very meaningful to study BP...
neural network and apply it to an example of handwritten Chinese character recognition.

1.1 Research Background and Significance

As an important cultural wealth of the Chinese nation, Chinese characters bear a long history of Chinese culture, and at the same time are the most important language tools for our communication and expression. Therefore, the research on Chinese characters recognition is an important part of the development of social life, scientific culture, humanities communication and so on. After entering the 21st century, the development of the times requires that work and life be rapidly intelligent and information-based. In the past, manual recognition in Chinese character recognition, inputting characters into computer system, etc. increased the manual workload, reduced the work efficiency and productivity, and made people’s work inconvenient. Therefore, the technical problems of handwriting Chinese characters for recognition need to be solved.

With the outbreak of the third industrial revolution, informationization, automation, intelligence and modernization have become the realistic needs of the rapid development of all walks of life. To a certain extent, the development of artificial intelligence is also a benchmark of national modernization. China has accordingly issued relevant policies to promote the development of artificial intelligence technology, such as “new infrastructure” and "internet plus", in an effort to lead the tide of artificial intelligence development. As a high-tech cutting-edge technology integrating many disciplines, artificial intelligence technology plays an important role in promoting the liberation of productive forces, improving work efficiency and helping industrial upgrading and transformation, and has a very far-reaching impact on the innovation of science and technology and the development of national economy. With the rapid development of computer technology, the field of deep learning and big data has also made great progress, and the field of artificial intelligence has also developed rapidly under its impetus. Deep learning has gradually become the focus of people's attention, and more and more scholars have begun to study the field of artificial intelligence. It makes deep learning popular in image recognition and other related fields.

Handwritten Chinese character recognition has attracted much attention in many fields, such as digital retrieval of documents, bank check processing, OCR (Optical Character Recognition) conversion, handwritten text input and other related fields. The introduction of computer vision technology enables users to quickly and conveniently input Chinese information, thus improving office efficiency and processing large quantities of Chinese information. Chinese Character Recognition is still an important problem in the field of image recognition. Although the recognition effect of the original "preprocessing+feature extraction+classifier" is acceptable, there are still many difficulties and shortcomings in the research of Chinese character recognition due to many confusing words, various types and complex structures. Handwritten Chinese character recognition, for standard Chinese characters, adds some problems such as writing standards, which makes handwritten Chinese character recognition still face many problems to be solved. After long-term research, deep learning put forward DBN (Deep Belief Network). DBN is very creative. It absorbs the training idea of unsupervised learning, enriches the neural network, rationalizes the model parameters, and can carry out hierarchical learning. Convolutional neural network, BP neural network and stack self-coding network, as well as network models that use different network structures to fuse for different tasks. The application of deep learning to character recognition has made great progress and breakthrough. Compared with traditional methods, it can solve the pain points in the process of Chinese character recognition, achieve better recognition effect and generalization ability, and has strong development potential.

Compared with printed Chinese characters, handwritten Chinese characters have the following characteristics:

1. Basic stroke changes.
2. Lian Bi phenomenon of strokes is very common in handwritten Chinese characters.
3. The position of stroke writing and the relative position between the radicals are also different. At the same time, stroke length is different, and straight line bending is also very common.

Generally, the handwriting fonts we mainly write are running script, regular script and cursive script. By comparing the three Chinese characters, it can be seen that the glyphs and strokes of the same character are different, or even far apart. Among them, some people can’t see what Chinese characters are written in cursive script. At this time, it is obviously difficult to ask the computer to recognize Chinese characters. Therefore, it is of great significance to study the computer automatic recognition of handwritten Chinese characters with different fonts.

1.2 Development and Present Situation of Domestic and Foreign Research

Handwritten Chinese character recognition is an important branch in the field of artificial intelligence and computer vision, and it is also one of the most challenging problems in OCR (Optical Character Recognition).
Initial stage: OCR technology was formally put forward in 1928 and began to be studied, which experienced the research process from printing to handwriting. In 1960, Casey and Nag of IBM (International Business Machines Corporation) successfully identified 1,000 printed Chinese characters by template matching, and achieved good results. At the same time, the research of handwritten Chinese character recognition has also attracted extensive attention. Liu et al. of MIT put forward features based on strokes of Chinese characters, and the weight vector corresponding to each feature is determined by the learning process similar to perceptron.

Because there are many similarities between Chinese characters and Japanese to a certain extent, in 1977, Toshiba Company of Japan began to study the recognition of Chinese characters, and designed a system that can recognize more than 2,000 Chinese characters. Then Musashino Company designed a recognition system that can recognize hundreds of printed Chinese characters in one second with an error of 0.02% , and can also recognize more than 2,000 Chinese characters.

Stage: Around 1970, some people in China began to study the recognition of Chinese characters written by opponents. After all, Chinese characters are the most widely used in China. Moreover, for the writing methods, rules and norms of Chinese characters, the domestic understanding is more thorough, so after that, the research on handwritten Chinese character recognition is mostly concentrated in China. Nantong Institute of Electronics and Shenyang Institute of Automation in China have developed printed Chinese character recognition systems . At this time, more and more ideas about printed Chinese character recognition have been put forward and introduced into the field of recognition: Nakano et al. began to study feature projection . Yamamoto et al. developed a framework that should be based on multi-resolution matching. At the same time, various variation methods are gradually applied to feature extraction of Chinese character recognition.

During this period, the development of various technologies also promoted the research of handwritten Chinese character recognition. For example, the Otsu algorithm in image processing is widely used in the process of converting gray image into binary image. Character adjustment and character blur were first proposed and studied as concepts, which also paved the way for the later Chinese character orientation feature extraction.

Development stage: Around 1980, the research on the recognition of printed Chinese characters began to have a qualitative leap. In 1985, Japan’s Fuji Company released a reading product that can recognize various printed Japanese fonts. At this time, China also launched the standard data set of commonly used Chinese characters, which contains 3755 most commonly used Chinese characters. Moreover, because Japanese characters are similar to Chinese characters to a certain extent, at that time, China also made great progress in the field of Chinese character recognition, and then slowly began the related research of off-line Chinese character recognition. At this time, algorithms such as neural network and quadratic discriminant function have also made great progress, which also promoted the research of Chinese character recognition, and put forward several well-known models, such as hierarchical neural network and implicit Markov model based on maximum mutual information standard. Various algorithms and models make Chinese character recognition develop rapidly.

Re-development stage: Since 2000, Chinese recognition has made great progress in China, and in-depth research has been made in all aspects. The recognition of Chinese characters has gradually formed a three-step recognition processing mode: image preprocessing, feature extraction and pattern classification.

In the aspect of preprocessing, the elastic grid method solves the problem of self-adaptive partitioning of Chinese characters with uneven overall distribution. The nonlinear method to regularize Chinese characters also puts forward a solution to the problem of writing differences of handwritten Chinese characters.

In the aspect of feature extraction, the direction line element feature and gradient direction feature also greatly improve the stability of direction feature.

In the aspect of pattern recognition, the design methods such as HMMs (Implicit Markov Model), CNN (Convolutional Neural Network) and LVQ (Learning Vector Quantization) and the method of comprehensive use of multiple classifiers further improve the recognition rate.

Since 2006, many new handwritten Chinese character databases have been published gradually, and the research direction has begun to develop from single-character recognition to multi-character recognition, which makes the recognition more authentic. At the same time, the combination of various neural networks and deep learning has begun to be applied to handwritten Chinese character recognition, which can adapt to various writing styles of handwritten Chinese characters with very good results.

As for the recognition application of BP neural network, in 2012, Ouyang Jun and others designed a new algorithm of license plate character recognition by combining the image processing method with BP neural network. Through a large number of BP neural network training.
and simulation experiments, the recognition speed and accuracy of license plate were greatly improved. In 2014, Liu Fang and others proposed an improved algorithm of character recognition with BP neural network, which improved the recognition rate and speed of characters in various noisy environments. In 2016, Li Dan and others carried out multi-character handwritten character recognition with any number of character templates. The accuracy rate of handwritten characters is over 95%.

BP neural network has great advantages in handwritten Chinese character recognition because of its good generalization ability, fault tolerance ability, self-learning and adaptive ability and nonlinear mapping ability. The model structure and optimization algorithm of BP neural network are constantly updated and improved, which also provides a good reference for off-line handwritten Chinese character recognition.

1.3 Research Content and Chapter Arrangement

On the basis of studying and analyzing the research background of BP neural network and handwritten Chinese character recognition at home and abroad, this paper illustrates the performance of BP neural network by training BP neural network from the aspects of Chinese character preprocessing, feature extraction method and the design of handwritten Chinese characters by BP neural network. The full text is divided into five chapters, which are as follows:

The first chapter is the introduction. Firstly, the research background and significance of this paper are summarized. Secondly, from the development process of handwritten Chinese character recognition and the development of BP neural network, the research status at home and abroad is expounded. Finally, the overall structure and chapter arrangement of the full text are introduced.

The second chapter is an overview of the preprocessing process of handwritten Chinese characters, which is introduced from the aspects of grayscale and binarization, smooth denoising, character cutting and normalization of handwritten Chinese characters, and gives the scheme steps of handwritten Chinese characters preprocessing.

In chapter 3, based on the preprocessed single character of handwritten Chinese characters obtained in chapter 2, the feature extraction methods of characters are analyzed in detail, and the most suitable image processing method is selected by comparing the results.

Chapter 4 illustrates the design of handwritten Chinese character recognition framework based on BP neural network. Firstly, the design and training process of BP neural network is analyzed. Secondly, the GUI interface is introduced. Then, the design of each module such as picture reading, preprocessing, network training and handwritten Chinese character recognition is introduced respectively. Finally, the results of handwritten Chinese character recognition are analyzed.

The fifth chapter is a summary of the work done in this paper, as well as the existing problems and future research ideas.

2. Preprocessing of Handwritten Chinese Character Images

The image used for recognition is usually a picture with multiple fonts, so it is necessary to preprocess the recognition samples to facilitate computer recognition. Moreover, for handwritten Chinese character recognition, the degree of optimization of image processing during preprocessing may directly affect the final recognition effect. Among them, the main processes of pre-processing include image gray processing, binarization, denoising, character cutting and so on.

2.1 Grayscale and Binarization of Chinese Character Images

2.1.1 Grayscale of Chinese Character Images

For an original picture, the content of the 256-color bitmap palette is very complicated. Therefore, we need to gray the image to reduce the data of the image. The process of converting a color image into a grayscale image through adjustment is called grayscale processing. The gray image of the image refers to a picture with the same R, G and B color components, and the values of the components are all between 0 and 255. There is no color difference in the whole gray scale image, only the difference in color brightness. Where the gray value is large, the pixels will be brighter, and where the gray value is small, the pixels will be darker. Therefore, gray-scale processing is actually the process of quantifying the brightness value. Transformation matrix of RGB color system and YIQ color system is as follows:

\[
\begin{bmatrix}
Y \\
I \\
Q
\end{bmatrix} =
\begin{bmatrix}
0.299 & 0.587 & 0.114 \\
0.596 & -0.274 & -0.322 \\
0.211 & -0.523 & 0.312
\end{bmatrix}
\begin{bmatrix}
R \\
G \\
B
\end{bmatrix}
\]

(1)

Y represents the transparency of the picture, that is, the gray value of the color, I represents the hue, and Q represents the saturation. Y contains all the information of the gray scale image, so a gray scale image can be represented only by the Y component. According to formula (1), we can find the value of y component:

\[
Y=0.299R+0.587G+0.114B
\]

(2)
Among them, the weights of R, G, and B are 0.3, 0.59 and 0.11, respectively. Figure 1 is a comparison chart of the effect of gray-scale processing of the original image.

![Grayscale the original image](image1)

![Grayscale result graph](image2)

**Figure 1.** Contrast chart of grayscale effect of color pictures

### 2.1.2 Binarization of Chinese Character Images

Before Chinese characters are segmented, it is necessary to binarize them to remove unnecessary information in the image. The binarized image can compress the image data and reduce the storage space. At the same time, it can also enhance the adaptability of the software. However, a lot of original information will be lost in the process of image binarization. How to retain the details of the original image to the greatest extent while binarizing is a big problem.

The function of transforming the gray scale image into binary image is:

\[
g(x, y) = \begin{cases} 
0 & f(i, j) > T \\
1 & f(i, j) \leq T 
\end{cases}
\]

where \( f(i, j) \) is the original image function, \( g(x, y) \) is the transformed image function, and \( t \) is the threshold value. Its function is to select the threshold, and then set the pixel to 255 or 0 according to the size relationship between the pixel in the image and the threshold.

There are many methods for image binarization, but their universality is usually not very good. Therefore, we should make a concrete analysis according to specific picture objects. The key to binarization of handwritten Chinese character recognition is to select a reasonable threshold. Now there are many methods for threshold selection, which can be divided into the following three categories:

1) **Local threshold method**

The local threshold method is a method to determine the local threshold according to the pixel characteristics around the target pixel. When identifying characters with more disturbances, the local threshold method can handle these disturbances well. However, its disadvantages are: the implementation speed is relatively slow, and the connectivity of the processed whole image cannot be guaranteed.

2) **Whole threshold method**

The whole threshold method can be divided into two categories: one is manually set, the other is determined by gray histogram.

1) manual setting

The artificial threshold is to get a reasonable threshold \( T \) according to the previous experience or our experimental results. If \( f(i, j) > T(i, j) \) is the background point, otherwise it is the pixel point on Chinese characters. This method is relatively simple, but it is not universal and has strong limitations. When the picture changes, the threshold cannot be automatically changed.

2) according to the gray histogram

This is to automatically determine the threshold through the gray image. Gray histogram can vividly describe the gray level of an image. The histogram should have two peaks, one corresponding to the background and the other corresponding to the Chinese characters. The threshold should be chosen at the valley between the two peaks. The deeper and steeper the valley is, the more obvious the binarization effect is.

3) **Dynamic threshold method**

This method mainly selects the threshold according to the position of pixel coordinates and the surrounding gray values. Mainly used for processing images with low quality. However, for handwritten Chinese character images, this processing method takes too long, so it is rarely used.

Generally speaking, the collected handwritten Chinese character images have high clarity and contrast, and the handwritten Chinese character part and background part can be clearly distinguished. Therefore, the overall threshold method can not only ensure the final image binarization effect, but also have relatively fast processing time. There will also be obvious differences in the effects after different threshold segmentation. If \( t \) is too large, interference will also be extracted; if \( t \) is too small, some information will be lost. Therefore, we choose the threshold according to the following rules:

1. If the gray level of the pixel is \( f(x, y) \) and the value of \( f(x, y) \) is 0–255, determine the threshold \( T \):
\[ T = \frac{(f(x, y)_\text{max} - f(x, y)_\text{min})}{3} \]  

(4)

The binarized effect image is shown in Figure 2.

(a) Grayscale image before binarization

(b) The result graph after binarization

Figure 2. Binary image rendering

2.2 Smooth Denoising of Chinese Character Images

There may be various noises in the sample image. The process of eliminating these noise components in the sample image and smoothing the image is called image denoising. De-noising is a technology in image enhancement. By de-noising, useful information in an image can be highlighted, and the noise mixed in Chinese character input can also be eliminated \(^{[32]}\). However, there may be noise in the Chinese character pictures that need to be processed, but it is not obvious enough. If the noise is directly removed, the effect will not be very good. Therefore, if the noise is not obvious enough, it is necessary to supplement the noise first and then remove the noise, which will have better effect to some extent.

Image noise is mainly divided into internal noise and external noise. The image noise has three characteristics: superposition, correlation between noise and image, and irregular distribution.

Image denoising is to do: firstly, the lines and other important information of the image can not be damaged, resulting in information loss; The second is to make the picture to be identified clearer. There are two main ways to improve the image: First, aiming at the image noise, use a specific method to compensate the influence of noise to eliminate the noise, and make the compensated image as close as possible to the original image. This kind of method is also called image restoration. Second, it doesn’t consider the cause of noise, only highlights the useful feature information of the image, and the improved image may not be completely consistent with the original image. It is mainly used to improve the identifiability of images.

In this paper, the median filter is used to remove the noise of the sample image. The median filter provides a good denoising ability for the random noise generated in. As shown in Figure 3, the \(3 \times 3\) neighborhood, where \(p\) represents the pixel to be processed, assumes that the pixel value of this pixel is 150 at this time, and investigates the surrounding eight pixel values, such as 67, 97, 160, 270, 300, 250, 120, 180 respectively. Among them, the median value is taken as the new value of the pixel gray of the center point, so the pixel value of \(P\) should take the median value of 160 after the 9 numbers are sorted by size.

![Median Filter](image)

Figure 3. \(3 \times 3\) neighborhood of pixel \(p\)

Considering that the handwritten Chinese characters used for recognition in this paper have little noise, the effect is not obvious or even worse after filtering. Therefore, we choose to use a smooth denoising step for the image. Partially smoothed denoising is shown in Figure 4.

(a) Binarization image before denoising

(b) Binarization image after denoising

Figure 4. Comparison before and after denoising

2.3 Chinese Character Segmentation

For Chinese character recognition, the original Chinese...
Chinese character pictures can’t all be samples of Chinese characters one by one. It may be that a picture contains many Chinese characters, and handwritten Chinese characters vary from person to person. People don’t always write according to the standard box, and there are great differences in position and writing size. Therefore, before handwritten Chinese character recognition, it is necessary to divide them into single Chinese characters of the same size to facilitate subsequent recognition.

At present, there are three main methods of character segmentation: the first one is based on structure, which is to analyze the structure between adjacent words to find the segmentation method; The second method is based on statistics, which is mainly used in the case of small differences in character widths. Find out the dividing line of characters through the overall distribution characteristics of characters. The third method is based on recognition, that is, before the image is segmented, identify all kinds of segmentation results of the image, and then identify the segmentation points according to the final segmentation results.

The character segmentation method adopted in this paper is vertical projection method:

At present, the vertical projection method is the most commonly used cutting method, which is simple to implement and faster than other methods. Firstly, the image area is projected in the row direction, and the statistical histogram of black pixels is obtained. The histogram part with Chinese characters will show a peak state, while the background part between Chinese characters will show a trough shape. After processing Chinese characters' rows, it can be divided into individual characters by the same projection in the column direction.

The specific implementation steps of single character segmentation are as follows:

First, read in the binarized picture, and extract the character height from the feature extraction link: d, and according to the mathematical formula of histogram:

\[ D(k) = \sum_{i=1}^{d} S(k) \]  

(5)

Draw a horizontal projection histogram D, and then detect and analyze the peaks and valleys of the histogram;

Then, according to the pixel distribution of the horizontal projection histogram, a reasonable threshold P is set to separate the character area from the non-character area, that is, to distinguish the rising point and the valley bottom point in the histogram. Among them, the threshold selection criteria are:

First, average the histogram:

\[ w = \frac{\sum_{k=1}^{D} S(k) \cdot K}{\sum_{k=1}^{D} S(k)} \]  

(6)

The minimum value of histogram is:

\[ e = MIN \sum_{k=1}^{D} S(k) \]  

(7)

Then average the sum of histogram average and minimum:

\[ r = \frac{w + e}{2} \]  

(8)

Get the optimal segmentation threshold r. After obtaining the best threshold, we scan from the left side of the Chinese character area to the rightmost side, compare the histogram of the k-th point with the threshold R. When D(k) is greater than the threshold, it is judged as the character area, that is, the k-th rising point, and create a sequence T to record the position of the rising point, which is denoted as T(k), and similarly, create a sequence Y to record the k-th valley bottom. When T(k) is less than or equal to the threshold value, it is judged as a non-character area, that is, the valley bottom point, and the number of statistical valley bottom points is recorded in the variable U, which is used to calculate the width of the k-th valley bottom, that is, D(k).

Figure 5 shows the projection histogram of handwritten Chinese characters.

Finally, each segmented single character is stored in the image and normalized, and the recognition result is displayed in the text dialog box.

The research object of this paper is relatively standard Chinese characters, so there are few cases of individual adhesion. Therefore, in order to ensure the processing speed and improve the system performance, the vertical projection method is used for segmentation. The segmentation effect of Chinese characters is shown in Figure 6.

2.4 Normalization

The segmented images are different in width and length of Chinese characters, so they need to be normalized to convert the images to be recognized into a unified standard form.

In handwritten Chinese character recognition, there are various changes such as size and position. Many normalization methods have also been proposed, which adjust handwritten Chinese character images to the same size by processing, so as to facilitate feature extraction and recognition.

In order to keep the original Chinese character features unchanged as much as possible, the normalization process
requires that the useful features contained in the image should not be changed. By normalizing the handwritten Chinese character images, the points belonging to the same category in the feature space can be closer. The processing of image normalization is mainly size normalization.

Character images of different sizes become Chinese characters of the same size after normalization. Methods The size of black pixels is normalized according to two directions, that is, the centroid GI, Gj of each Chinese character is calculated according to formula (9), then the divergence in I and J directions is calculated according to formula (10), and finally the Chinese character image is scaled up or down into a dot matrix of specified size.

\[
\begin{align*}
G_i &= \frac{\sum_{i \in A} \sum_{j \in B} i \cdot c(i, j)}{\sum_{i \in A} \sum_{j \in B} c(i, j)} \\
G_j &= \frac{\sum_{i \in A} \sum_{j \in B} j \cdot c(i, j)}{\sum_{i \in A} \sum_{j \in B} c(i, j)}
\end{align*}
\]

(9)

\[
\begin{align*}
\sigma_i^2 &= \frac{\sum_{i \in A} \sum_{j \in B} c(i, j) \cdot (i - G_i)^2}{\sum_{i \in A} \sum_{j \in B} c(i, j)} \\
\sigma_j^2 &= \frac{\sum_{i \in A} \sum_{j \in B} c(i, j) \cdot (j - G_j)^2}{\sum_{i \in A} \sum_{j \in B} c(i, j)}
\end{align*}
\]

(10)

In the formula, c(i,j) is a numerical lattice, and U, D, L and R are the four boundaries of Chinese characters, respectively. As shown in Figure 7, the images of Chinese characters are normalized by using 0–255, 0–1 and the normalization function provided by Matlab respectively.
tion effect for handwritten Chinese characters is basically the same, so this paper chooses the normalization function of Matlab to normalize.

2.5 Histogram Equalization of Chinese Character Images

2.5.1 Principle of Histogram Equalization

The histogram of an image is a statistical chart that reflects the distribution characteristics of pixels in an image. It represents the distribution curve of the image data that is dark on the left and bright on the right, instead of directly displaying the original data. The cost of image processing is relatively small, but sometimes good results can be obtained. Among them, the value of abscissa represents each pixel feature, and the value of ordinate represents the number of pixels of different color elements in the image.

The purpose of histogram equalization processing is to transform the gray values from the relatively concentrated gray areas through formula (11) according to the gray histogram of the original image, so that the gray values are evenly distributed in all gray areas. In this way, the range of gray values can be increased, thus achieving the effect of enhancing the overall contrast of the image.

\[
h(v) = \text{round}\left(\frac{\text{cdf}(v) - \text{cdf}_{\min}}{(M \times N) - \text{cdf}_{\min}} \times (L - 1)\right)
\]

(11)

where \(m\) and \(n\) represent the number of pixels in the length and width of the image respectively; \(L\) is the gray scale; \(V\) is the pixel value of \(V\) in the original image; \(\text{cdf}_{\min}\) represents the minimum value in the cumulative distribution function.

Histogram equalization is roughly divided into three steps: first, count the number of each gray level in the histogram; Then, the histogram is shown; Finally, the new pixel value is calculated by the formula.

2.5.2 Histogram Equalization for Image Enhancement

For images with poor binarization effect, histogram equalization is carried out, which makes the gray values of pixels evenly distributed again, thus enhancing the image contrast and better selecting the threshold of image binarization.

Generally speaking, histogram can improve the quality of the image after image enhancement, so it is very useful for image processing. In this paper, histogram equalization is used to enhance individual images that are difficult to binarize to improve the recognition rate of images.

2.6 Summary of This Chapter

This chapter mainly introduces the preprocessing process of handwritten Chinese character images. Firstly, the image is processed by gray scale and binarization. For the image with poor effect, the histogram is enhanced before binarization. Secondly, the single Chinese character is segmented by line cutting and single character cutting, thus preparing for the next feature extraction.

3. Comparison and Selection of Handwritten Chinese Character Feature Extraction Methods

In the last chapter, after preprocessing the handwritten Chinese character image, a binary image of a single Chinese character is obtained, but it is obviously unreasonable to train and classify the binary image directly. First of all, too much image data and too much computation are unacceptable to the system; Secondly, if a lot of irrelevant information in the image is involved in the identification process, it will not only increase the workload, but also reduce the accuracy of identification, even make it impossible to classify. In any recognition process, the first step is to analyze the features and select the most representative features.

The most important thing for feature selection and extraction of handwritten Chinese characters is how to find the most representative features from all image features without losing the information of handwritten Chinese characters images.

3.1 Brief Introduction of Feature Extraction Method

In the recognition of images, it is unrealistic to classify the preprocessed images directly. The feature extraction process of Chinese characters is to find out the most representative feature vectors. There are many feature extraction methods for character recognition, which can be roughly divided into two categories. One is feature extraction method based on statistical features, and the other is feature extraction method based on structure. Statistics-based feature extraction can be extracted from binary images, while structure-based feature extraction can be extracted from the thinned skeleton after preprocessing, and the structural features of characters can better reflect local details.

Different features can show different aspects of the described things, and the extraction methods of statistical features and structural features have their own advantages and disadvantages. Statistics have strong adaptability to classifiers, but they are not sensitive to noise and have relatively good stability. However, structural features are sensitive to the changes of detail features, and can well distinguish small changes. However, structural features...
are too sensitive to noise, and if noise is not handled well enough, there will be unpredictable recognition consequences.

Turn the extracted feature vectors of training samples into the input of the network, train the BP neural network, and then input the features of the samples to be recognized into the trained BP neural network, so that the characters can be recognized. For different recognition objects, feature extraction methods should be selected within the demand range. The following will summarize the commonly used feature extraction methods in Chinese character recognition.

Handwritten Chinese character feature extraction methods mainly include pixel-by-pixel feature extraction method, skeleton thinning method, elastic grid feature extraction method and many other methods, which can be selected according to our actual situation.

3.1.1 Feature Pixel by Feature Extraction Method

Feature-by-feature pixel extraction method is to select the sample image that has been binarized row by row and column by column, and take its feature value as 1 when the white pixel is found, or take its feature value as 0 when the black pixel is found. Then we can get a feature matrix composed of all sample feature values. This method is relatively simple, which is the most obvious for the training effect and can make BP neural network converge quickly, but its disadvantage is that it is not adaptable and insensitive to changes. Therefore, more training samples are needed to make it more adaptable.

3.1.2 Skeleton Thinning Feature Extraction Method

For handwritten Chinese characters, the same Chinese character written by different people will have a lot of recognition difficulties due to different writing methods and different line thicknesses. However, after thinning them, the line width of each Chinese character is unified to a fixed pixel width, so that the difference is not obvious. Then, the thinned Chinese character skeleton is used as a feature for training and recognition, which makes the system have certain adaptability. However, once the position deviation occurs in this method, it will be difficult to identify it.

The structural features of skeleton are mainly divided into trunk features and edge contour features:

(1) It refers to the main part of Chinese characters, mainly including the length and width of each Chinese character, the shape of strokes, etc. When extracting the features of handwritten Chinese characters, the first thing to determine is the changes of inflection points, endpoints and intersections of Chinese characters.

(2) Edge features: Edge features refer to the distance from the outermost periphery of each Chinese character to the picture boundary, etc.

3.1.3 Elastic Mesh Feature Extraction Method

If the grid is evenly distributed in the horizontal and vertical directions, we call it a uniform grid; However, if the Chinese characters are divided according to the strokes and concentration degree of Chinese characters, the grid which is non-uniform in both horizontal and vertical directions is non-uniform grid, which is also called elastic grid. Generally speaking, an elastic grid will be determined according to the histogram of Chinese characters in both horizontal and vertical directions. The feature extraction method of elastic grid is as follows:

(1) Firstly, determine the grid number n, m of the grid, and generally take n = m for convenience of calculation;

(2) Applying projection to obtain projection values Horn(i) and Vert(i) in the horizontal and vertical directions;

(3) According to the calculation formulas (12) and (13) of the net wires, determine the non-uniform net wires ii and jj in the horizontal and vertical directions;

\[
\sum_{i=1}^{n} \text{Horn}(i) = x_{i}, \quad i = 1, 2, \ldots, K, I_j
\]

\[
\sum_{j=1}^{m} \text{Vert}(j) = x_{j}, \quad j = 1, 2, \ldots, K, I_i
\]

(4) Divide the Chinese character image into corresponding elastic grids according to the obtained values of ii and jj, and then calculate the proportion of black pixels in each grid.

(5) Finally, the feature vectors in each grid are combined to form a feature vector, which is used as the feature of Chinese characters. This vector is the elastic grid feature vector.

3.2 Selection of Handwritten Chinese Character Recognition Feature Extraction Method

3.2.1 Selection Principle of Handwritten Chinese Character Feature Extraction Method

Selecting appropriate feature vectors is the key step of character recognition, and the selection of feature vectors is also one of the core tasks of character recognition. The principle of feature selection is: firstly, we should adapt to our own samples, and secondly, we should choose a method with strong classification ability; Then the dimension of features should be reduced as much as possible to
reduce the complexity and difficulty of system operation as much as possible, and improve the running speed and recognition accuracy of the whole system. In short, when all the requirements cannot be fully met, reasonable trade-offs and balances should be made, either by improving the recognition rate or by improving the running speed of the system, so as to meet their own requirements as much as possible.

For different recognition things and different data sets, different feature extraction methods can meet different demands. The best choice method is to select the most important details for recognition according to experience and knowledge. You can also compare different functions to find out the most classified information. It can also be verified by real simulation to determine the best method.

3.2.2 Selection of Feature Extraction Methods

By comparing the experimental results of feature extraction of samples with different methods (as shown in Figure 8), it is found that this paper is more suitable for feature extraction by pixel:

![Figure 8. Schematic diagram of different feature extraction methods](image)

(a) Elastic mesh (b) Skeleton thinning (c) Pixel by pixel extraction

Pixel-by-pixel feature extraction method has the best training effect for a single character, and its relative running speed is relatively fast, but its disadvantage is that it is insensitive to details changes.

Skeleton thinning feature extraction can well reflect the details of Chinese characters, but the recognition rate is not very high because of too sensitive noise.

![Figure 10. Error rate of skeleton refinement feature extraction and recognition](image)

The feature extraction method of elastic mesh can well reflect the main part of Chinese characters, but it is also sensitive to noise, and it is easy to recognize errors in noisy images.

![Figure 11. Error rate of elastic mesh feature extraction and recognition](image)

Therefore, finally, the pixel-by-pixel extraction method with high recognition accuracy is selected, and the feature vector of each Chinese character is formed by scanning the binary image line by line and column by column, and the feature value of the Chinese character part is 1 and the feature value of the background part is 0. Finally, the obtained feature matrix is stored in the array matrix prepared for implementation. Provide data for the following BP
neural network training.

3.3 Summary of This Chapter

This chapter mainly introduces three feature extraction methods of handwritten Chinese characters: pixel-by-pixel extraction method, skeleton thinning feature extraction method and elastic grid feature extraction method based on the preprocessed images in Chapter 2, and compares the three methods for data sets, and finally selects the pixel-by-pixel extraction method with the highest recognition rate for this article as the feature extraction method of data sets. In order to prepare for the fourth chapter, the extracted feature vectors are sent to the neural network for training and recognition.

4. Handwritten Chinese Character Recognition Based on BP Neural Network

Handwritten Chinese character recognition is a kind of pattern recognition, which distinguishes different Chinese characters according to the features and details of each picture. Common methods of image recognition include support vector machine, template matching and neural network. The neural network has better self-learning ability, adaptive ability and very good fault tolerance. Multiple samples can be trained. Therefore, for the recognition of handwritten Chinese characters, this paper chooses BP neural network as a classifier to complete the recognition of handwritten Chinese characters.

4.1 BP Neural Network Model

BP neural network learning algorithm is a popular neural network learning algorithm at present. It is a multilayer feedforward network that corrects the error layer by layer through reverse transmission. Analyze the error between the results obtained from each training and the expected results, and then modify the weights and thresholds, step by step to get the model whose output is consistent with the expected results. The nonlinear I/O mapping relationship is reflected by the weight and structure of the network. At the same time, BP neural network can repeatedly adjust the weights and thresholds through training the known samples until the transmission relationship of the network reaches the output standard. The neurons in the same layer of BP neural network are independent without mutual connection, but the neurons in different layers are connected. In addition, the hidden layer can have one layer or many layers. Because the calculation method of the whole network goes forward layer by layer, it also belongs to the forward network \(^{(33)}\).

\[ f(x) = \frac{1}{1 + e^{-x}} \] (14)

Therefore there are:

When the neuron is the input layer unit, \(OK = x_k\);

(1) For the \(k\)th sample, the \(j\)th neuron can be described as:

\[ \text{Net}_{ji} = \sum_{i} W_{ij}O_i + \theta_j \] (15)

(2) The output of the \(J\)-th neuron is:

\[ \text{Net}_{j} = \sum_{i} W_{ij}O_i + \theta_j \] (16)

(3) Error between actual output and expected output:
\[ E = \sum K_k = \left( \sum (d_{ij} - O_{ij})^2 \right) / 2 \]  
(17)

(4) The weight correction formula of BP network is:

\[ \Delta W_{kj}(t+1) = \eta \delta_k O_j \]  
(18)

Type for the output layer using the formula:

\[ \delta_k = (d_{ij} - O_{ij})(1 - O_{ij})O_j \]  
(19)

For the hidden layer, the formula is used:

\[ \delta_k = O_{kj}(1 - O_{kj}) \sum \delta_{mi} W_{mj} \]  
(20)

The learning rate \( \eta \) in the above equation is the step size of gradient search. The larger \( \eta \) value, the more intense the change of weight. In practical application, the maximum \( \eta \) value is taken under the condition of ensuring that it will not cause vibration. The parameter \( \alpha \) is added to the weight formula in order to speed up the learning, and at the same time, it also controls the system not to be prone to oscillation. \( \alpha \) indicates the influence degree of the past weight on the current weight:

\[ \Delta W_{kj}(t+1) = \eta \delta_k O_j + \alpha \Delta W_{kj}(t) \]  
(21)

4.3 Design of Handwritten Chinese Character Recognition System Based on BP Neural Network

For the BP neural network, the actual output value of the neural network is related to its input value, the number of hidden layers, the thresholds and weights of each layer. Only the neural network with good weights and thresholds can make the actual output value and the expected output value of the network finally agree. The biggest feature of BP neural network is to adjust the weights and thresholds between networks through continuous training, so that the error between the output of the network and the expected output can reach the expected value.

This paper is a research on the background design of some handwritten Chinese characters based on BP neural network recognition, so the first task is to determine the structure of BP neural network for handwritten Chinese characters recognition.

4.3.1 Overall Design of BP Neural Network Training Framework

Learning and training are the key steps of BP neural network. Through training, the digital information in feature extraction can be stored in the network, that is, the network is used as a medium to establish a correspondence between input and output. The training process of BP neural network in this paper is shown in Figure 13:

![Figure 13. BP neural network training process](image-url)

(1) Initialization, fix the weights and thresholds of BP neural network, because in Matlab, the initialization weights and thresholds of neural network are random. If these parameters are not fixed, the neural network will get different results every time, which is not uniform. Fix the random number by the following statement:

```
rand(152, ‘twister’); The value in% fixed random number can be modified at will.
```

(2) According to the order of data set, the feature vector of the first picture is first read as the input of neural network, and the output of each node in each layer is calculated from the input layer.

(3) Calculating the error value between the current sample data and the corresponding output layer;

(4) Modify the weights and thresholds layer by layer from the output layer to the front;

(5) A round of training is conducted on the data set samples. Considering that one training may not reach the
final expected value, the input is processed once and the training is conducted for many times. The code is as follows.

Input=[Input Input Input]; % repeat training
Output=[Output Output Output];

(6) detecting whether the total network error meets the requirements, if so, ending the training, otherwise, returning to step (2) and continuing the training.

4.3.2 System Parameter Tuning of BP Neural Network

The most important thing to design a BP neural network is to choose various parameters. Determining the number of network layers, initial weights, learning algorithms and number of nodes is equivalent to determining the BP neural network. Although the selection of these parameters mainly depends on experience, there are certain guiding principles.

(1) Determination of hidden layers of BP neural network

The number of hidden layers of BP neural network is uncertain, but the more hidden layers, the smaller the system error. When the number of hidden layers is too large, the errors generated by the network may decrease, but with the increase of layers, the training time of the whole system will be longer, and the transmission errors between layers will also increase. BP neural network with only one hidden layer can be used to realize continuous functions in any interval, which has strong applicability. Therefore, this paper chooses to use a network structure with multiple neurons in a single hidden layer. That is, what we usually call the three-layer network structure.

(2) Transfer function of BP neural network

When training BP neural network with data set, it can be found that when using logarithmic transfer function as neuron training function in output layer and hidden layer, the error will be much smaller than that when using piecewise function or threshold function. Therefore, this design adopts logarithmic sigmoid function as the function of hidden layer and output layer.

(3) Selection of learning rate

Learning rate is also a very important variable for the training of neural network. Its value can affect the span process of each training of the network; If the learning rate is very small, it will take many iterations to reach convergence. If the learning rate is very high, the error requirement may fluctuate repeatedly, or even exceed the local minimum value, which may lead to the inability to converge. According to experience, the choice of learning rate will be between 0.01 and 0.8. This paper is set at about 0.05.

(4) Expected error

The setting of the expected error value should be selected according to the convergence of the network. Generally speaking, if the network is easy to converge, you can choose the smaller expected error. If the network is not easy to converge, the expected error value should be appropriately increased.

(5) Determination of the number of hidden layer nodes

For systems with many classifications, the requirements of hidden layer are relatively high. If there are too many nodes in the hidden layer, the training time may be too long. However, if the number of nodes is less selected, the identification accuracy of the network may be poor and the identification task cannot be completed. Generally speaking, according to the known number of input nodes and output nodes, we should train and compare the networks with different number of nodes to find out the one with the smallest error as the best number of nodes. In this paper, the growth method is used to train the neural network with fewer nodes, observe the change of learning error, and then slowly increase the number of nodes until a relatively satisfactory learning error is obtained.

Training the three-layer BP neural network has the following empirical formula to learn and select the number of nodes for reference:

\[ k = \sqrt{l + o + u} \]  (22)
\[ h = \log_i \]  (23)
\[ h = \sqrt{o} \]  (24)
\[ k = 2i + 1 \]  (25)

where I is the number of nodes in the input layer, H is the number of nodes in the hidden layer, O is the number of nodes in the output layer, and U is any integer between [1,10].

The training results are shown in the following table.

**Table 1. Relationship between Number of Hidden Layer Nodes and Error**

<table>
<thead>
<tr>
<th>The number of neurons in the hidden layer</th>
<th>training error</th>
<th>test error</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1.25441</td>
<td>1.1563</td>
</tr>
<tr>
<td>7</td>
<td>0.99514</td>
<td>0.9215</td>
</tr>
<tr>
<td>9</td>
<td>0.61452</td>
<td>0.6927</td>
</tr>
<tr>
<td>11</td>
<td>0.580315</td>
<td>0.6896</td>
</tr>
<tr>
<td>13</td>
<td>0.552777</td>
<td>0.6535</td>
</tr>
<tr>
<td>15</td>
<td>0.455114</td>
<td>0.6575</td>
</tr>
<tr>
<td>17</td>
<td>0.38725</td>
<td>0.6483</td>
</tr>
<tr>
<td>19</td>
<td>0.296714</td>
<td>0.4527</td>
</tr>
<tr>
<td>21</td>
<td>0.173878</td>
<td>0.6538</td>
</tr>
<tr>
<td>23</td>
<td>0.169833</td>
<td>0.47</td>
</tr>
<tr>
<td>25</td>
<td>0.168479</td>
<td>0.6571</td>
</tr>
</tbody>
</table>

According to the above table, the following conclusions can be drawn:

1) The number of nodes in the hidden layer can reduce the training error, but after 19 nodes, the error starts to
rise, indicating that its generalization ability has changed, which is comparatively available. The number of nodes between 19 and 21 can be selected as the number of nodes in the hidden layer.

2) The error is always very large, which can be improved by adjusting the initial weight and learning rate. After experiments, it is decided that the learning rate is 0.05, which can achieve the expected goal.

![Iterative error of neural network](image)

**Figure 14.** Iterative error of neural network when the number of hidden layer nodes is 21

4.3 Simulation and Implementation of Handwritten Chinese Character Recognition System Based on Matlab

For different Chinese character recognition systems, except for the feature extraction method and recognition method, the other steps are a relatively similar process. The recognition process of this paper is: firstly, by reading Chinese character pictures, pre-processing the pictures to be recognized, training the BP neural network with the pictures in the data set, and then, after post-processing, comparing the final recognition results and outputting them as strings.

Based on the pretreatment of the first two chapters and the principle of BP neural network, the feasibility of handwritten Chinese character recognition by BP neural network is verified, and the results of handwritten Chinese character recognition are shown. Recognition includes the steps of graying, binarization, interference removal, segmentation, network training, handwritten Chinese character recognition and so on.

4.3.1 Design of GUI Interface

GUI interface is a graphical user interface for us to execute applications in the computer. We can get the steps we want to achieve in the display window by selecting different buttons and menu options to realize interpersonal interaction. Making GUI interface is mainly through building the corresponding event-driven system, that is, clicking the corresponding button will execute the corresponding program segment, and return the corresponding information in the window, and then wait for the next operation of the user. As shown in Figure 15.

![GUI interface](image)

**Figure 15.** GUI interface

### 4.3.2 Handwritten Chinese Character Data Set Acquisition Module

The establishment of data set is mainly to select representative Chinese characters to train BP neural network. The training of data set is a necessary condition for Chinese character recognition, so before starting to recognize Chinese characters, the data set should be established first.

At present, there are about 4,000 Chinese characters commonly used in China, and handwritten Chinese characters that vary from person to person, even those written by the same person, may be different, so the collected characters should reflect universality.

In this paper, 17 Chinese characters, such as Chinese, Chinese, local, qualitative, big and academic, are collected to establish the data set. The establishment process is as follows:

1. Save the handwriting in jpg format to the computer;
2. Preprocessing the sample to obtain a binary image;
3. Cut into individual Chinese characters and store them in the data set;
4. Select a part of the segmented binary handwritten Chinese character image as a data set to train the neural network, and the collected samples are shown in Figure 16;

Handwritten Chinese character recognition system based on BP neural network can be roughly divided into three parts: input image, preprocessing of handwritten Chinese characters and BP neural network recognition of Chinese characters after preprocessing. Among them, the input is data set and test set image. Firstly, the BP neural network is trained with the preprocessed feature vectors.
of the data set, and then the trained BP neural network is used to identify the Chinese characters in the test set. In this paper, the segmented single-character binary image to be identified is transformed from left to right and from top to bottom in turn, and transformed into the feature vector of each character. If the pixel value is 255, the characteristic value is 1, and if the pixel value is 0, the characteristic value is 0. Finally, the feature vectors are input into the trained neural network for recognition. The system has buttons in the GUI interface for each step, which can clearly reflect the identification process of each step.

4.3.3 Chinese Character Preprocessing Module

Preprocessing: It mainly includes the processes of image gray processing, binarization, denoising, image segmentation and normalization. Its main contents have been described in detail in Chapter 2.

(1) First, the Chinese character pictures are read into the system, then grayed and binarized, and the blank background of the font is set to 0, and the part with black font is set to 1. Therefore, the image can be expressed as a binary data matrix composed of 0 and 1.

Figure 16. Partial Sample Data Map

Figure 17. Pretreatment process
(2) Then cut the binary image. First, get the characters of each line, then cut each line separately, number each single character and display it in the interface of the system.

4.3.4 Network Training and Identification Module

In the part of neural network training, the training process of neural network is also a key step in recognition. Through the training process, the feature information of each Chinese character can be connected with the network, that is, the feature input of each Chinese character can establish a corresponding relationship with the output of neural network, and the corresponding feature output can be obtained by inputting a feature value, thus achieving the purpose of recognition. The training process of BP neural network has been explained in Chapter 3.

According to Figure 19, the accuracy of network identification after training can basically meet the requirements, and the identification function can be completed. The recognition result shown in Figure 20 can be obtained.
4.4 Analysis of Experimental Results

4.4.1 Test Results

In order to verify the performance of the handwritten Chinese character recognition system, this paper selects 10 test pictures for recognition verification. When the samples in the data set and the samples in the test set are used for recognition, two results will be obtained:

(1) When the sample of the data set is used as the recognition image, the recognition accuracy can reach 100%, and the simulation value is basically consistent with the output value.

(2) When the test set picture is used as the recognition image, there will be the possibility of recognition errors. In this example, there are three recognition errors in 17 Chinese characters, as shown in Figure 21.

![Figure 21. Partial recognition results](image)

4.4.2 Analysis of System Identification Performance

**Table 2. Sample recognition rate**

<table>
<thead>
<tr>
<th>sample source</th>
<th>number of correct</th>
<th>correct rate(%)</th>
<th>Error rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>data set</td>
<td>17</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>test set</td>
<td>15</td>
<td>94</td>
<td>6</td>
</tr>
</tbody>
</table>

Through multiple groups of sample tests, it can be seen from Table 2 that for the data set, the correct rate of samples can reach 100%, while there are errors in the training set, among which, the error rate of “Chinese” and “self” is the highest, and “self” is often identified as “medium”.

By comparing the experimental results, we can see that the reasons for the decline of recognition accuracy are as follows:

1. Data set samples are still insufficient. In the case of less training, BP neural network can’t be well trained, and it is very effective to build a representative data set, which can quickly improve the network performance.

2. The characteristics of handwritten Chinese characters change relatively greatly. For two similar Chinese characters, there may be recognition errors due to different writing styles. The method of feature extraction can be optimized to stabilize the system performance.

3. The network structure is relatively simple. For a single BP neural network to recognize handwritten Chinese characters, it is still very difficult to adapt to various styles of Chinese characters. The combination of BP neural network and other networks can be used to improve the recognition rate.

According to the above experimental results, we can know that the number of data sets and the diversity of data in them will be an important factor affecting the final recognition result of BP neural network. When the data set sample is large enough, it will have better recognition effect after learning by BP neural network. At the same time, the training parameters of BP neural network are also an important influencing factor, and the rationality of the parameters can also determine the final recognition result.
4.5 Summary of This Chapter

This chapter mainly introduces the simulation and implementation of handwritten Chinese character recognition in Matlab software. Firstly, the composition of each part of handwritten Chinese character recognition system is introduced. Then it introduces the design of GUI interpersonal interface, and the recognition process of handwritten Chinese characters through GUI interface. Finally, based on the test results and the training data of BP neural network, the influencing factors of handwritten Chinese character recognition are analyzed. The simulation results show that the handwritten Chinese character recognition system based on BP neural network can complete the recognition function and has high recognition accuracy.

5. Summary and Prospect

5.1 Summary

Handwritten Chinese character recognition has always been a very important direction in the field of pattern recognition. The research on handwritten Chinese character recognition is not only helpful to our study and life, but also promotes the development of pattern recognition. For a long time, as Chinese characters are the common words of the Chinese nation, foreign scholars have not studied them very deeply, and the uncertainty of handwritten handwriting also makes the recognition of handwritten Chinese characters even more difficult. Therefore, it is of great significance and value to study off-line handwritten Chinese character recognition and improve the accuracy of handwritten Chinese character recognition.

This paper studies the construction and learning process of BP neural network, the design and implementation of handwritten Chinese character recognition based on BP neural network. Through the pretreatment of Chinese characters, learning with BP neural network, and finally verifying the feasibility of recognizing handwritten Chinese characters with BP neural network through Matlab recognition simulation. The work is divided into the following four parts:

(1) The research background and significance of handwritten Chinese character recognition, the historical development of handwritten Chinese character recognition and some research processes are systematically described, and some examples of Chinese character recognition by different methods are listed.

(2) The pretreatment process of handwritten Chinese characters is introduced in detail. Comprises five steps of gray scale processing of handwritten Chinese character pictures and histogram enhancement, binary processing, smooth denoising, Chinese character cutting and normalization of some handwritten Chinese character pictures, and then stores the pictures.

(3) Analyze the feature extraction methods of handwritten Chinese characters, and select the most suitable method for this paper by comparing the advantages and disadvantages of different methods.

(4) In this chapter, the framework of written Chinese character recognition based on BP neural network is described in detail. The model and parameter characteristics of BP neural network are summarized, and then the design scheme of BP neural network is put forward. The modules of GUI man-machine interaction interface in Matlab are explained. Finally, the simulation of handwritten Chinese character recognition process based on BP neural network is studied. And the simulation results are analyzed. Firstly, it is explained that the platform used in the simulation test is Matlab. Then, image preprocessing and network training are carried out on the sample pictures. Finally, the feasibility of recognizing handwritten Chinese characters by BP neural network is verified through recognition, which has good practical significance.

5.2 Outlook

Because of the time and energy constraints, this paper still has many shortcomings in recognizing handwritten Chinese characters by BP neural network. The following are the deficiencies and further planning:

(1) There are too few samples used to train BP neural network in this paper, which leads to the inability to accurately identify other Chinese characters after the same network training, and has certain limitations. After that, it can be improved from the following aspects: First, increase the training sample set for training BP neural network; Second, some limitations in improving procedures.

(2) The preprocessing process of Chinese characters may need to be further refined, or different preprocessing methods may be tried to improve the feature extraction method to improve the recognition efficiency and accuracy.

(3) At present, only Chinese characters in simple background can be recognized, and the recognition effect of block letters is very good. After that, we should try to see if we can recognize Chinese characters in complex background and Chinese characters with different fonts.

(4) In the next step, BP neural network can be combined with other classifiers to find a more efficient combination of classifiers to supplement the shortcomings of BP neural network.
References


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