Study of Highly Efficient Algorithms for the Character Recognition System of Medicine Bottle Label

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Abstract **—This paper studied character recognition on medicine bottle label containing batch number, production date and expiry date. It mainly consisted of character location, character segmentation and character recognition. Firstly, it preprocessed the image of medicine bottle label for the following procedures; secondly, it obtained the general character region by contour tracing and realized the precise location by horizontal projection algorithm; then it located character adhesion region by vertical projection algorithm and segmented the merged characters by drop fall algorithm; finally, it adopted Karhunen-Loeve transform to extract character features from the subclasses of coarse classification and accurately recognized characters by the improved BP algorithm. Experiments show that the system can recognize the bottle label characters quickly and accurately, it is of great practical value.**

Index Terms**—image processing, character location, character segmentation, character recognition system, BP neural network**

I. INTRODUCTION

Due to the close relationship of medicine quality to people's life and health, the state department of pharmaceutical administration is strict in drug testing requirements. Medicine packaging labels include batch number, production date and expiry date, which conveys very important information about the medicine, so character recognition of bottle label plays an important role in medicine testing. With the continuous improving of Optical Character Recognition technology[1], the technology is relatively mature and has been widely used in many fields such as vehicle license plate recognition[2], bill recognition, certificate identification of information collection, but the correct rate of character recognition will decline apparently if it is associated with specific work scenarios to satisfy specific requests such as images with low quality and lots of interferences like adhesion and fracture characters. Thus character recognition technology is still in a research and exploration stage, it is of great research significance to apply the character recognition technology to character testing of medicine bottle label.

The task of character recognition algorithm is to recognize the characters of medicine label, it includes three major parts: positioning of character region of medicine label, segmentation of character region [3] and recognition of character region [4]. In terms of character positioning, International and domestic scholars have made lots of research on the method of license plate location [5]. But medicine label can't achieve a satisfactory result by only using a license plate positioning method because it is different with the characteristics of license plate label [6] such as fixed character number, fixed height and width of license plate characters. So this paper proposes a new positioning method that combines contour tracking method [7] with projection method [8], and finally realizes the precise location [9] of character region. At present, the research of character segmentation mainly focuses on the segmentation method of template matching method, projection method and region growing method. Because the characters of medicine label have multiple formats and adhesion regions, there may exit many errors if region growing and projection method are used in this paper. Although the template matching method can well identify the characters, the computational complexity is still large and the running time is long because the variable formats of medicine label characters. This paper first uses the vertical projection method [10] to locate the adhesion region, and further adopts the drop fall algorithm [11] to segment the adhesion characters; the correction rate is enhanced largely by using the coarse and detailed segmentation. About the character recognition, artificial neural network is a new technology on pattern recognition, which uses artificial neural network to realize recognition of patterns. It has the

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advantages of good fault-tolerance , self-adaptability and so on, while the BP neural network [12] have solid theoretical basis, rigorous derivation process, clear physical conception and good versatility, many problems can be solved by it, so this paper uses the improved BP neural network [13] to recognize characters more accurately and quickly.

II. IMAGE PREPROCESSING

A. Image Gray Processing

The processing algorithm of color image is complex and needs a long operation time, it is better to convert color image to gray image which only contains brightness information with 256-level gray scales. The conversion formula for gray image and color image is:

$$Y = 0.299R + 0.587G + 0.114B \tag{1}$$

B. Character Distortion Correction

Because the medicine bottle is a cylinder and the image of the vial label surface is arc-shaped, so it is essential to make a distortion correction to the image. The distortion correction algorithm adopted in this paper is specifically described in the next segment.

As is shown in Fig. 1, points of c and d are the corresponding points of b and d that are unfolded to the plane from the cylinder surface, the length of b and d is longer than that of a and c. The inconsistency of length varies with the position, that is, the character distortion is small in the center and larger on side edges. The unfolding process of correcting perspective projection plane into cylindrical surface plane is a non-linear amplification process. To the cross-sectional view of a vial cylinder, the radius R of the cylinder is divided into n equal parts, the length of each part is a, and the corresponding actual lengths of the cylinder surface respectively are $a_1, a_2, a_3, \cdots, a_i, \cdots a_n$, θ_i is the included angle of a_i and the horizontal radius, where

$$n \times a = R \tag{2}$$

$$\cos\theta_i \times R = i \times a \tag{3}$$

$$a_i = (\theta_{i-1} - \theta_i) \times R \tag{4}$$

Substituting (2), (3) in (4), then

$$a_i = (\arccos(i-1) \times a / R - \arccos(i \times a / R)) \times R \tag{5}$$

According to the derived mathematical formula, the corresponding coordinate of the source image is deduced by the coordinate of target image by using the method of reverse mapping, and the gray scale to the point of the non-integer coordinate is determined by linear interpolation. Thus, the vial label image with distortion characters is corrected by a non-linear process. The effect of distortion correction can be seen in Fig. 2:

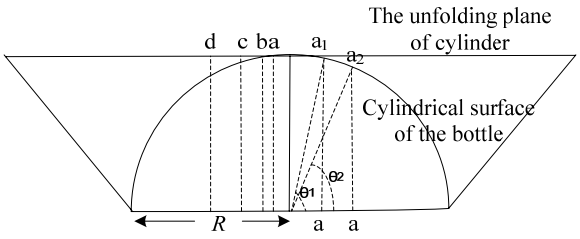


Figure1. Distortion correction theory

(a) Before distortion correction (b) After distortion correction

Figure2. Effect of distortion correction

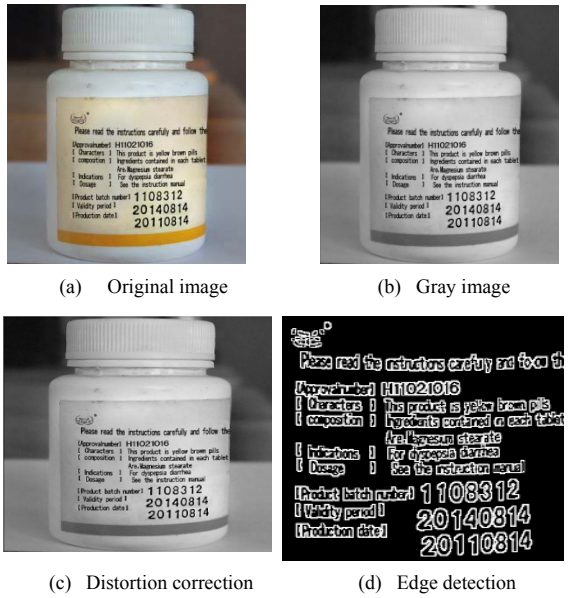
C. Image Smoothing

Due to the influences of scene condition and other factors, the image may be accompanied by noise interference, so there will be some deterioration to image quality, so we need to smooth the noise. Median filtering [14] is a classic method of noise smoothing, a 3*3 median filter is chosen in this paper.

D. Edge Detection

The edge contains a lot of abundant information which is important to image segmentation. The algorithm Laplacian of Gaussian operator can have accurate detecting result and good edge continuity, so LOG algorithm is adopted to detect the edge [15] in this paper.

By now the pretreatment of the image has been finished, the treatment effect is shown in Fig. 3:



(a) Original image (b) Gray image

(c) Distortion correction (d) Edge detection

Figure3. Effect of pretreatment

III. CHARACTER LOCATION OF MEDICINE BOTTLE LABEL

The target of character positioning is to find out the location of medicine label from the complex image and segment the label region from the image, it is an indispensable part in the character recognition system of medicine label. The positioning accuracy directly influences the following character segmentation and recognition. According to the character feature of medicine bottle label, this paper proposes a new positioning method which is the combination of contour tracing method and projection algorithm.

A. Rough Positioning of the Character

Step 1 we first use the method of mathematical morphology [16] to carry on a horizontal expansion operation to the preprocessed image, and use structural elements {[-1, 0], [0, 0], [1, 0]} to divide the whole image into several connected regions, then mark them.

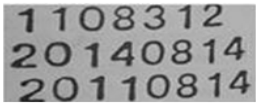
Step 2 Then the connected character region is extracted by contour tracking method, which is described as follows: First, it searches the boundary points from left to right and bottom to top, and the bottom left white boundary point be found is regarded as the first boundary point. Beginning with the first boundary point, it defines the initial search direction is along the upper left; The point on top left will be a boundary point if its color is white, otherwise rotate the search direction 45 degrees clockwise and go on to search until the first white point is found. Then regarding the white point as a new boundary point, the method anticlockwise rotates 90 degrees on the basis of current search direction and continues to search next white point in the same way, all boundary points will be found until it returns the original boundary point. Meanwhile, we respectively count the width and height of the highest point and the lowest point in each connected region. Based on experiments and priori knowledge, we extract the connected region that satisfies two below functions and assign 128 to pixel values in the extracted region.

$$MaxPo\text{int}.Height - MinPo\text{int}.Height >= 170 \quad (6)$$

$$MaxPo\text{int}.Height - MinPo\text{int}.Height < 230 \quad (7)$$

Finally, after scanning the whole image, scan the whole image again from the top left, 255 is assigned to all the pixel values of 128, the obtained white area is the approximate area where the target characters of image locates. By now we have completed the rough location of characters, whose treatment effect is as the following Fig. 4:

(a) Morphological processing (b) Contour tracing



(c) Rough character region

Figure4. Effect of rough character location

B. Accurate Positioning of the Character

It is need to locate target character accurately for there may exist some interference regions in the approximate area. Fig. 5 shows the general flow of accurate location:

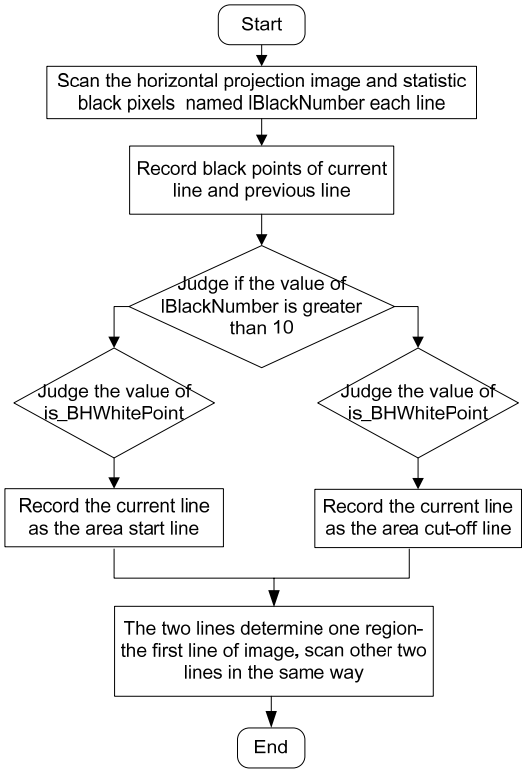


Figure5. Flow chart of rough character location

First, we project the rough positioning image to horizontal direction, then scan the projected image line by line to obtain the black pixels named lBlackNumber each line; then we set a variable of BOOL style called is_BHWhitePiont to judge the number of black pixels last row, if the number is greater than 10, the value of the variable is FALSE, otherwise it is TRUE.

After the above two steps, we continue to judge the obtained values. If the value of lBlackNumber is greater than 10 and the value of is_BHWhitePiont is TRUE, the current line will be recorded as the start line of the first

region. The other two lines are obtained in the similar way. In the end, we extract the character region of each line and realize the accurate location of character. The result is shown in Fig. 6:

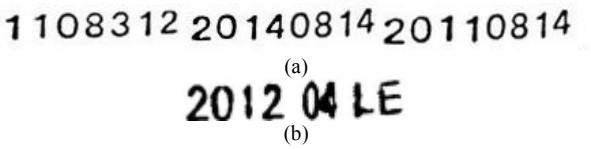


Figure6. Effect of accurate character location

IV. Character Segmentation of Medicine Bottle Label

After the character positioning, the characters of the drug label may be broken and connected, so we first use the expansion method combined with the closing operation to solve the fracture problems, but this may lead to connection of the characters. In order to solve this problem, this study presents a method that combines the rough segmentation based on vertical projection and accurate segmentation based on drip algorithm. The general flow is as Fig. 7:

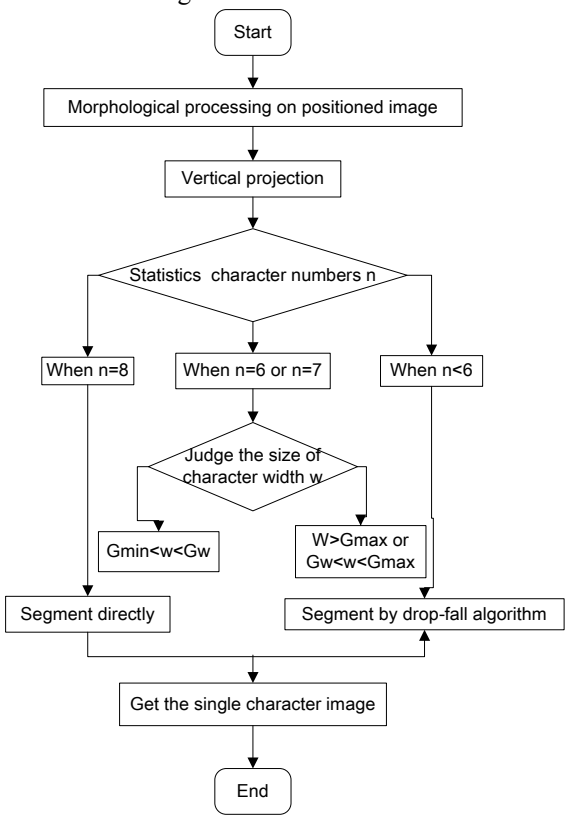


Figure7. Flow chart of character segmentation

A. Rough Segmentation based on Vertical Projection

Step 1 Assuming a binary image whose size is M*N, its vertical projection in column j is:

$$V(j)=\sum_{i=1}^{M} g(i,j) \qquad j=1,2,\cdots,N \tag{8}$$

The process of vertical projection is described as: scan each column of image from left to right, and find the first point j_{a1} where $V(j)\neq 0$, then regard j_{a1} as the left boundary of the first character; we continue to scan images to the right, because the area whose projection value is zero corresponds to the blank space of the characters, then find the first point j_{b1} where $V(j)=0$ and put it as the right boundary of the first character. Other characters are obtained in the same way. The method counts out the total character number named n and calculates the width named w of each character, which is described as:

$$j_{bi}-j_{ai} \qquad i=1,2,\cdots n \quad 6\le n\le 8 \tag{9}$$

Step 2 We have counted the total character block number n from the last step, and actually the character form can be divided into three types, that is, the character number is 6, 7 or 8, the Chinese characters appearing in the medicine label are only Year and Month, where the error segmentation of left and right components does not exist, here follows the different situations:

- If n=8, character image can be directly segmented, and the result we get is the right segmentation result.
- If n=6 or n=7, we can't judge the character image based on vertical projection is the right result, it is need to judge the character width. According to the prior knowledge, we know that the minimum character width is $G_{\min}$, maximum character width is $G_{\max}$, the character mean width G_w is set as half of the sum of $G_{\min}$ and $G_{\max}$. If the character width is greater than $G_{\max}$, there must exist the phenomenon of character adhesion, then continue to go to the accurate segmentation in next section; if the character width is between G_w and $G_{\max}$, then the character picture may exist the phenomenon of character adhesion, and we can enter the next section as well; if the character width is between $G_{\min}$ and G_w, the character picture does not exist the character adhesion, then we can directly use the vertical projection in step 1 to segment.
- If n=6, there must exist character adhesion in character image, then directly enter the next section.

B. Accurate Segmentation based on Drop-fall Algorithm

After the above coarse segmentation, in this section we make a further detailed segmentation by the drop-fall algorithm. Its basic idea is segmenting a string by imitating the natural dripping process of water-drop from a height to the lower place. Under the action of gravity, the water-drop can only drop along the outline of the character from the string top or scroll in horizontal direction. When the water drops into the recess of contour, it will penetrate the character strokes and continue to drop down. Eventually, the rolling track of dripping water constitutes the segmentation paths.

The mathematical description of drop fall is as the following: Assume that the character image that needs to be segmented is P, the height of image is N, the width is M. Then a coordinate system is established, the coordinate point on top left is used as the origin O. Then convert he character image to binaryzation image, "w" represents the black, "b" represents white. Now the segmentation path T depends on the current pixel value and the adjacent pixel value, the formula is:

$$T(x_{i+1}, y_{i+1}) = f(x_i, y_i, W_i), i = 0,1,2,\ldots \quad (10)$$

In which (x_i, y_i) represents the current pixel coordinate, (x_0, y_0) represents the starting point of the segmentation path, W_i represents the direction of movement, whose value depends on the adjacent pixels n_1, n_2, n_3, n_4, n_5 (as Fig.8 shows)·

$$w_j = 6 - j, (j = 1,2,3,4,5) \quad (11)$$

$$W_i = \begin{cases} 4 & if \sum = 0 \ or \ 15 \\ \max_{j=1}^{5}(1 - Z_j)w_j & else \end{cases}$$, in which

$$\sum = \sum_{j=1}^{5}(1 - Z_j)w_j \quad (12)$$

$$T(x_{i+1}, y_{i+1}) = f(x_i, y_i, W_i) = \begin{cases} (x_i - 1, y_i) & if \ W_i = 1 \\ (x_i + 1, y_i) & if \ W_i = 2 \\ (x_i + 1, y_i + 1) & if \ W_i = 3 \\ (x_i, y_i + 1) & if \ W_i = 4 \\ (x_i - 1, y_i + 1) & if \ W_i = 5 \end{cases} \quad (13)$$

Based on the above formulas, the method can ensure the motor process of water droplets and find the character segmentation path. The principle of drop-fall algorithm is shown in Fig. 9:

n_5	n_0	n_4
n_1	n_2	n_3

Figure8. The neighborhood pixels of n_0

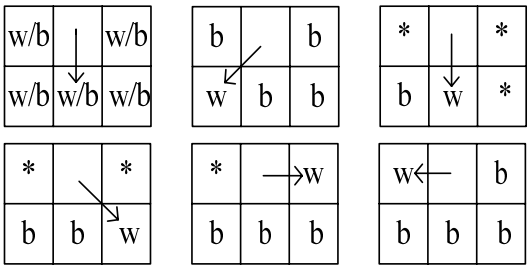


Figure9. The principle of drop-fall algorithm

Character segmentation has been completed successfully by now, the segmentation result of is shown in Fig. 10:

(a) Vertical projection (b) Character segmentation

Figure10. Effect of character segmentation

V. The Character Recognition of Medicine Label

If we extract image features [17] directly and put them into BP neural network to be identified, it not only requires a lot of training samples, but also finally leads the computer to large calculation, long time consuming and slow rate convergence. Based on the current study of character recognition methods, this paper first uses the simple structural features and statistical features of characters for a rough identification to minimize the number of classes in each subclass; then it extracts the optimal feature of the classified characters by K-L transform, making sure the character features input to the BP neural network can accurately reflect the character attributes without any redundant information; finally , the paper accurately recognizes characters with high recognition rate of BP neural network.to similar characters. The flow chart is as follows:

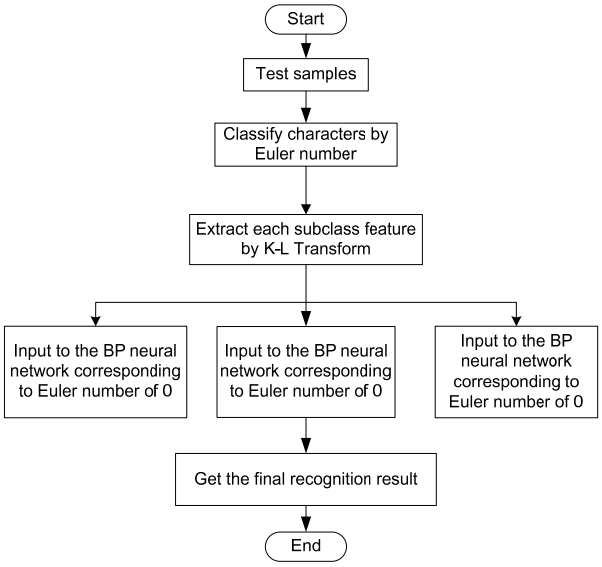


Figure11. Flow chart of character recognition

A. Rough Recognition

After splitting, formed single-character picture is often different sizes, In order to be easy to achieve the method of Feature extraction. Firstly, choose bilinear interpolation to normalize images for the character size of 32*24, and then divide the characters based on characters features of Euler number into three groups to complete a rough classification:

The characters that Euler number is-1: 8, B;

The characters that Euler number is 0: 4, 6, 9, A, D, O, Q, P, R;

The characters that Euler number is 1: other numbers and Letters of the alphabet.

B. K-L Transformation

Karhunen-Loeve Transform [18] is often referred to as "the best transformation", because it can completely remove the signal correlation and have the best statistical characteristics. If it is applied to the recognition the drug label character, the extraction process of character feature can be simplified so as to improve the recognition accuracy [19]. Its transformation idea is to seek the orthogonal matrix A, the transformed signal corresponding to the covariance matrix is a diagonal matrix. To the stationary random vector x whose mean value is u_x, the covariance matrix is defined as:

$$C_x = E\left[(x-\mu_x)(x-\mu_x)^T\right] \tag{14}$$

$$C_x = \begin{bmatrix} c_{0,0} & c_{0,1} & \cdots & c_{0,N-1} \\ c_{1,0} & \cdots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \vdots \\ c_{N-1} & \cdots & \cdots & c_{N-1,N-1} \end{bmatrix} \tag{15}$$

$$c_{i,j} = E[(x(i)-\mu_x)(x(j)-\mu_x)] \tag{16}$$

Here shows the steps of Karhunen-Loeve Transform method: Based on the N order polynomial $|\lambda I - Cx| = 0$ of λ, the eigenvalues $\lambda_0 \cdots\cdots \lambda_{N-1}$ of matrix C_X are obtained; according to the formula $C_x A_i = \lambda_i A_i$, the eigenvectors $A_0, A_1, \ldots, A_{N-1}$ of matrix C_X are got, which are normalized by making $\langle A_i, A_i \rangle = 1$; then they constitute matrix A that satisfies $A = [A_0, \ldots, A_{N-1}]^T$; At last, the formula $y = Ax$ successfully realizes the Karhunen-Loeve Transform.

C. The Design of BP Network Structure

Because of the disadvantages of traditional neural network algorithm such as slow convergence speed and easily falling into local minimum, this paper adopts the improved BP algorithm [20]which is the combination of adaptive adjusting learning rate with dynamic regulating S-type excitation function, the algorithm adjusts the slope of the excitation functions of each hidden unit and output unit.

(1). The improvement of BP neural network algorithm

In the traditional BP neural network algorithm [21], the adjustment formula of the weight is $\Delta w = -\eta \frac{\partial E}{\partial w}$, in which E is the global error function. We can see from the formula, the value of learning rate η is fixed, which greatly affects the convergence speed and stability of the algorithm. If the learning rate is too large, it can improve the convergence speed, but it will lead to the consequence of network oscillate and even divergence; if the learning rate is too small, it can ensure the training a stable convergence, but the time of training would be very long and the convergence speed is slow. So we adopt an adaptive method to adjust the learning rate, whose main idea is growing the learning rate when error decreases and reducing the learning rate when error grows. The concrete practices are as follows:

$$\eta_t = \eta_{t-1}(1-\alpha\Delta E) \tag{17}$$

In which η_t is the tth time iteration value of the learning rate, ΔE is the error increment, $0<\alpha<1$ is constant. From the formula we can see, when the value of ΔE is greater than 0, it means error grows and the weight has been adjusted so large that the value of Δw needs to be decreased. From formula $\Delta w = -\eta \frac{\partial E}{\partial w}$ we know, Δw will reduce if η decreases. On the contrary it can be concluded that η will grow if ΔE is less than 0. It can speed up the convergence rate and ensure that no network shocks because of the too large value of ΔE.

On the other side, traditional BP neural network chooses the S function whose derivative is $f(1-f)$, if the net input value of neurons is too large or too small, the output result will enter a saturated zone, which can lead to a large error. In the meantime we will find the "platform" and even no convergence phenomena in the error curve. In this article we enlarge the error to settle this problem, we can give new values to the error signals both the output layer and the hidden layer, which makes the error factor $f(1-f)$ magnified to $-\ln[f(1-f)]$ times. It can be seen from the image of the formula $g(x) = -\ln[x(1-x)], \quad x \in [0,1]$, when the output value of the neuron is 0 or 1, the error signal would increase quickly, which affects the correction of weights. So we can avoid the training of neural networks into the state of saturation region by the improved BP neural network.

(2). The parameters setting in the BP neural network

The neurons number in the input layer depends on the size of the pixel characteristic dimension from the characters that need to be identified. This system normalizes the characteristic dimension to obtain the image characters with the size of 32 × 24 dot matrix, then extracts the characters' best feature of each subclass by the method of Karhunen-Loeve Transform, finally takes the feature dimension that is obtained by every subclass as the neurons number in the input layer;

With the number of nodes in the hidden layer increasing to a certain extent, computational complexity increases correspondingly, the convergence speed of the network training reduces, and generalization ability of the network will be poor at the same time, so it is necessary to select the appropriate number of hidden layer unit. Meanwhile, too small number of neurons may make training a network fall into local minimum point. Too many neurons will make the network training time too long, so the effect is not necessarily good. In consideration of the methods many scholars put forward, this paper selects s to be the number of hidden node, m to be the number of input node and n to be the number of output node according to the empirical formula: $s = \sqrt{m \times (n+1) + 1}$

The neurons number in the output layer depends on the output expression and decision rules while designing the network. The neurons number in the output layer is the number M of categories that to be identified, every neuron in the output layer represents a target category.

VI. Experiment Results

According to the above principle, three different BP neural networks are designed to recognize the characters obtained from the three subclasses that derived from the coarse classification. The process of BP neural network identifying the medicine label characters is as the following Fig. 12:

(a) (b)

Figure12. Recognition result

Based on the characteristics of the medicine label characters, this paper designs three classifiers. Table 1 is the test result which shows that, the neural subnet recognition rate is 97.3% when Euler number is -1, because the number of characters into this classifier is relatively small, and there exits a clear distinction between the characters, so it has a higher recognition rate. The neural subnet recognition rate is 96.9% when Euler number is 0, and the neural subnet recognition rate is 97.1% when Euler number is 1, this is caused by the similar structure of some characters such as O, D, S, the recognition neural network is difficult to distinguish between them with the consequence of the false recognition. But judging from the overall results, the improved BP neural network has a good learning and fault tolerance capacity, and it will reduce the recognition time using the Karhunen-Loeve Transform method to extract the best features after the rough classification. In conclusion, the system in this paper can recognize the characters of the image with high speed and accuracy.

TABLE I.

TESTING RESULTS OF BP NEURAL NETWORK

	Sample number	False recognition number	Recognition rate
Euler number is -1	74	2	97.3%
Euler number is 0	228	7	96.9%
Euler number is 1	519	15	97.1%
Total	821	24	97.1%

VII. Conclusion

Medicine labels are closely related to people's life and health, according to the characteristics of medicine bottle label, this paper mostly studies the algorithms of character location, character segmentation and character recognition in the character recognition system. The character location is realized by the combination of contour tracking method with projection method, while the character segmentation is completed by the vertical projection method together with the fall drop algorithm, the character recognition is obtained by using the improved BP neural network. Lots of repeated sample tests show that the character recognition algorithm in this paper can recognize the characters in the image quickly and accurately. But this article is just the study of label on medicine bottles, the drugs also include some rectangular cartons with bar codes on the packaging, so the algorithms also need to be improved. In additional, the priori knowledge is not the same to different sizes of bottles, so we should set different segmentation thresholds according to different sizes of bottles. The system can not achieve complete automation, there still needs a further improvement and enhancement.

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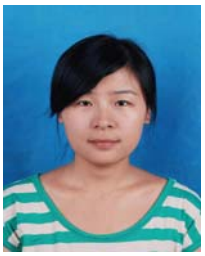

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