Offline Handwritten Signature Recognition Method Based on Multi-features

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Abstract

This paper studies the off-line handwritten signature recognition technology and fusion strategy, proposes a fusion identification method. The skeleton and four corner features are extracted, BP neural network is used to identify true and false signature. The edge feature is extracted, Euclidean distance is adopted to recognize true and false signature. The experiment results show the method can effectively improve the recognition speed and correct recognition rate by combining BP neural network and Euclidean distance recognition in decision fusion.

Keywords: Skeleton Feature, Four Corner Feature, Decision Fusion

1. Introduction

The signature is widely used biometric identity, and it plays an important role in social life. The technology of automatic signature recognition has strong practical value and application prospect [1,2]. Handwritten signature has wide and good development prospects in many areas such as the national defense, justice, finance, communication.

Signature recognition technology has some advantages such as sufficient dynamic information, difficult imitation, higher discrimination, and efficient access to information, and the characteristics of the collecting features, body injury acceptability and robustness are very outstanding [3]. Improving signature recognition quality and speed has important theoretical value and practical significance in Chinese information processing, artificial intelligence.

Signature recognition is divided into offline and online system. Offline system researches for two-dimensional static image signature, it converts the original handwritten signature to image information by photoelectric conversion principle. The extraction features include the location of the signature, shape, the direction of the stroke, the collocation between strokes and so on [4].

The online system is to study the dynamic process of generating signature, namely signature behavior itself, it is a form of sampling point sequence through the writing pad to realize sampling point collection and input. Each sampling point is described by its position in the writing pad. The extracted features include pen movement speed, acceleration, pressure, pen movement direction and so on.

The online system needs the devices such as tablet, therefore the application is fairly limited, and the signature are generally completed through the ordinary bills and paper in finance, bank, detection and other fields [5]. If the amount is larger or in view of some special need, it needs to use computers to help artificial identification experts to identify, it is time for offline signature recognition. Therefore, the offline signature recognition system just overcomes the limitation of application range for online system, and there is a wide range of potential application market. This paper considers the offline signature recognition [6].

The handwritten signature recognition has been studied for over 30 years abroad, and made a lot of achievements, especially the quite mature online signature identification. Some developed countries have many mature commercial automatic online signature identification instruments. Because offline signature provides less information, and it is of greater difficulty, the research achievements are relatively less than online signature, there is not a practical offline signature recognition system [7,8]. Due to the Chinese signature with large amount of words, font, complicated structure, big writing
change, Chinese offline signature recognition still does not have a practical and effective method to achieve higher correct recognition rate.

Now, the researchers are devote themselves to improving the recognition rate of handwritten signature. Most studies focus on the signature feature selection, the collection of the original features, the calculation of statistical features and the mutual comparison, the feature comparison of user distinction and etc. Sample training mode mainly includes the statistical methods and machine learning methods [9,10].

This paper respectively extracts the skeleton, four corner features, and edge feature after pretreatment handwritten signature image. The skeleton and four corner features are extracted, BP neural network is used to identify signature. The edge feature is extracted, Euclidean distance is adopted to recognize signature. The experiment results show the method can effectively improve the recognition speed and correct recognition rate by combining BP neural network and Euclidean distance recognition in decision fusion.

2. Handwritten signature recognition methods

The handwritten signature images will contain a lot of useless information and interference noise obtained by the cameras or ordinary scanners, and therefore it needs to preprocess the signature images in order to obtain a valid handwritten signature. Handwritten signature recognition effects depend on the good or bad feature extraction algorithms, and how to extract the most effective signature feature is one difficult problem in the paper. Comparison and decision for handwritten signature is based on the comparison and recognition of the extracted features and the real signature to give the authenticity judgment.

2.1 Preprocessing

The preprocessing reads the signature image and implements denoising processing, the gray processing, the double-precision floating-point processing, the binarization, the stroke refining and the size normalization. The gray processing, the double-precision floating-point processing and the binarization are helpful to pattern recognition, the stroke refining and size normalization are benefit of feature extraction.

According to the difference of the feature extraction, the different signature recognition system takes different preprocessing steps. The signature image preprocessing usually includes image smoothing, binarization, gray correction, normalization, thinning, tilt correction, and contour extraction. In the phase of image acquisition, it scans signature through the machine or digital camera to collect signature images. The collected signature images are generally influenced by the light, the focusing of digital camera and filming circumstance such as jitter, and the background noise and other factors of signature image, it leads to the obtained bad signature images, which can affect the results of signature recognition. In order to improve the effect of the original image and better extract the effective signature features, the preprocessing is necessary.

In order to improve the quality of signature image and eliminate noise, this paper uses the median filtering method to deal with the noise of the original image. 256-color palette of the bitmap is complex, so it is necessary to do the gray processing in order to reduce the image data. The so-called gray image is that R, G, and B component values are equal in the image, there is no difference of color in gray image, only the different brightness is different. The pixels with larger gray value is brighter (the maximum pixel value is 255, white), otherwise darker (the minimum pixel value is 0, black). There are many different methods for gray processing. This paper respectively adopts the weighted coefficient of RGB pixel value, then add them, at the same time, correspondingly process the palette. Image binarization also has a lot of mature technology, including dynamic and fixed threshold technology, the paper uses fixed threshold method to separate the signature from the background.

In the all kinds identified texts, the stroke with different length and thickness, even if the same stroke is also different in different text and fonts, after their lines are refined, the obtained uniform width such as in a pixel width, the difference is not obvious. The basic refinement requirements are as follows. Keep the continuity of the original strokes, reduce broken strokes as far as possible, refine it into a single line, namely the width of stroke is a bit, the refined skeleton should be the center line of the original stroke as far as possible, maintain the original features of the text, neither increase nor lose.
There is a bigger difference in character size of the input image, but relatively speaking, the recognition with the same signature size is easier and more accurate. The standardized image is to transform the different signatures to the same size, the method is to obtain the height of the original signature, compare the height of the system, get the transformation coefficient, obtain the width according to the coefficient, after obtain the width and height, map the points of the new image to the original image according to the interpolation method.

2.2 Feature extraction for signature image

Because of the diversity and complexity of handwritten signature, looking for image features of good description and classification performance, as well as the extraction of these features become the crux of the handwritten signature recognition based on features. Biological features used as identification should include these characteristics. The universality, everyone should have this characteristic, the uniqueness, each people has the unique characteristic, the stability, the features don't vary with time, external conditions, the collectability, the selected features should be easily measured.

In signature recognition, the feature classification mode is numerous, the commonly classification is global features, statistical features and geometric shape structure features.

The global features adopt entire signature as the feature extraction unit, taking the parameters of overall features obtained from the entire signature as the features. The features have stronger anti-jamming ability, convenient matching classification, and faster speed, but the distinction ability of the signature details is weak, and sensitive to the signature deformation, it is generally used for the random and simple pseudo signature detection. The specific signature features include signature center of gravity, inclined features of signature, moment, and the coefficient obtained from mathematics transform. The signature center of gravity is to seek signature barycentric coordinates, the signature inclined features is the whole inclined features between the signature and the horizontal direction, the moment features are of scale, translation and rotation.

The statistical features take the statistical information such as signature pixel value, special points, strokes or stroke direction, and the location distribution as features. The characteristics of the whole deformation by signature influence is relatively minor, and it is often used in many literatures. The specific features include segmentation-based statistical features, projection and texture features. The segmentation-based statistical features are to extract statistical feature of each region or primitives after image segmentation. Projection is in the central, horizontal or vertical projection. The texture provides linear, orientation and periodic property measurement and so on, the general method is gray co-occurrence matrix.

The shape features include the global and local signature features, it main represents global or local signatures shape structure features and the structure relationship among relevant stroke segment. Such characteristics on signature deformation tolerance is best, and parts of the shape features are of scale and translation invariance. The specific features include shape descriptor and geometric structure features, and the shape descriptor is used to describe the signature outline, the geometric structure feature is reflected signature shape structure and the stroke segment change.

The features for offline signature identification include global, local, pseudo dynamic, texture features and some moment features and so on, in addition, wavelet transform, Garbor filter can also be used for signature image feature extraction. This paper extracted signature image skeleton feature of pseudo dynamic features, four corner features of shape features, edge character of structure features.

The specific process of skeleton extraction including the steps. Image preprocess, and then image correct and minimum border process, divide the image into 288 area of 24*12, calculate the pixels, finally output the obtained skeleton features. The four corner feature is based on different style of signature for everyone, when everyone writes his own name, likes a strong individual feature in a few strokes, based on this reason, this paper extracts the four corner feature.

The concrete realization process is to scan the pretreated image from top left corner, if the current density is greater than the specified threshold density, it is considered to be appear font, then compute the pixel points within the five current radius, five range is to improve the precision. If there is no greater than the specified threshold density, then the radius adds one, continue scanning, until find it. When finish the first corner, then collect the second corner. In order to facilitate the processing, the paper uses the image rotation method until the four half-angle features are got.
Edge detection is very important foundation of image segmentation, target area identification, region shape extraction and other image analysis fields, and it is also an important attribute of feature extraction in image recognition. Edge detection appears in the form of local feature discontinuity. Namely it is the remarkable section of local image change in brightness, such as the mutation of gray value, the mutation of color, the mutation of texture structure, and at the same time, the edge of the object is the boundary of different regions. Image edge has direction and amplitude features, the gray usually changes gentle along the edge of the direction, the change of the pixel is violent perpendicular to the edge of direction.

In practical application, general operator is in the form of differential operator in order to be simple, then use the fast convolution function to realize, this approach can get quick and effective effect. The commonly used differential operator includes Log operator, Roberts operator, Canny operator, Sobel operator. This paper uses the Canny operator to extract the edge feature of signature image.

Canny operator is a kind of optimal edge detection operator, and it has been widely used in many image processing areas. The Canny method adopts Laplacian operator, it uses two different thresholds to respectively detect strong and weak edges, and the weak edges are included in the output image only when the weak and strong edge are connected. Compared with other methods, it is not easy to be filled with noise, and it is easier to check the real weak edges.

2.3 Fusion strategy

People and animals perceive an objective in nature not only depending on a certain organ but also the fusion of several organs. The vision, hearing, smell, taste of human actually get different information through different organs, then the information is fused under the control of the brain. The process of more sensory information fusion is called data fusion. The multi-biological characteristic authentication is the application of data fusion in the biological certification.

Different biological authentication may use different biological characteristics, specific model and method from the biological authentication itself, but the basic process is consistent. The process of biometric authentication is the course of pattern recognition about biological characteristics. Pattern recognition can be roughly divided into three processes: feature extraction, template matching and decision-making. According to the process, the fusion of multi-biological characteristics can also correspondingly be divided into three levels: feature fusion, matching fusion and decision fusion. The study for the latter two fusion is more than the first fusion.

The feature fusion is the set of feature vectors extracted from different biological characteristics. The different feature vectors use different methods to constitute a new high-dimensional feature vectors represented the fusion of biological characteristics.

The input of the matching fusion module is the score of the matching module of several biometric authentication systems. The fusion of the matching layer is for these inputs and it is the most common in the three fusions. The reason is that matching fusion has relatively small difficulty and merges the information of each feature. The very important for matching fusion is the normalization for the score of different systems. After the moralization, the scores of different systems are mapped to a N-dimension space in which all points are classified. The main classification methods include the sum rules, the decision tree method, and the linear distinguish function and so on.

The decision fusion is relatively simple and it can make use of relatively small amount of information. The input of the decision is the logic output of single biometric authentication. As a result, the decision fusion can be divided into two forms.

(1) OR rules. In this system, if the user is refused by subsystem $H_1$ and the subsystem $H_2$ will once again verify the user. If this is adopted, the user will be identified as the real user.

(2) AND rules. In such a system, only when the user is accepted by the subsystem $H_1$ and subsystems $H_2$, the user can be identified as a real user.

From the above analysis, we can see the amount of information is decreasing according to the feature fusion, the matching fusion to the decision fusion. That is to say, the feature fusion has used the most information. The fusion of image information can be divided into three layers from low to high according to the abstraction of information: feature fusion, matching fusion, and decision fusion. This paper adopts the decision fusion which is at a high level, decision fusion deals with a small amount of data, and it can increase the speed of recognition.
2.4 Handwritten signature recognition method

As the final stage of the signature recognition, the results are mostly depending on the effect of feature extraction. This stage mainly recognizes and judges the authenticity of the preprocessed and feature-extracted signature image to be verified, and matches the extracted features with the characteristics of the real sample to obtain the result. There is no algorithm for all case in this stage, so the recognition results may be various because of different recognition algorithms.

At present, the main signature identification methods includes distance-based classifiers (Euclidean distance, Mahalanobis distance), neural network classifier, classifier based on template matching, support vector machine and hidden Markov model. The principles of identification methods are different, the performance of various identification method has its own merits.

Euclidean distance is a simple method of statistical classification with distance indicating similarity. It refers the signature image features to be identified and the characteristics of the image of the training samples to calculate the Euclidean distance between them. If the distance is greater, the similarity is lower, and the authenticity of the signature image is more doubtful. When it is less than a certain threshold, it can be directly determined as a true signature, otherwise, it is a false signature. Euclidean distance identification method requires to set the threshold, while the determination of the threshold can only be determined by empirical value.

Euclidean distance between the two samples \( X_i = (x_{i1}, x_{i2}, x_{i3}, \ldots, x_{in})^T \) and \( X_j = (x_{j1}, x_{j2}, x_{j3}, \ldots, x_{jn})^T \) is as follows. After extracting the edge feature of signature image, this paper adopts Euclidean distance to recognize.

\[
    d_{ij} = \sqrt{\sum_{k=1}^{n} (x_{ik} - x_{jk})^2}
\]  

Hidden Markov model is also involved in statistics, and it is one of Markov chain. The state can be obtained only through the observation vector. The observation vector, generated by the probability density of the state sequence, is the probability density distribution performance of state. HMM model takes the Baum-Welch algorithm to train the model, and it is formed by training the status number and the transition probability of the signature. Take the features extracted from the signature image on recognition stage as observation sequence and input it to the trained HMM model to calculate the given observation sequence, and the HMM model produces the probability of the observation sequence. Although HMM has achieved good results in the field of speech recognition and face recognition, it has many limitations, and it has few application in offline signature recognition.

There are many models of artificial neural network, and the Hopfield neural network, forward multilayer neural network (such as BP algorithm, RBF network), ART network, self-organizing feature map network are commonly used at present. The multilayer feed-forward neural network and error back propagation learning algorithm referred to as the BP neural network. BP neural network is most widely used. BP neural network has the powerful mapping relationship between input and output, it can map an input pattern to the desired output mode to achieve the correct recognition effect simply by training the input object. After extracting the skeleton and four-corner characteristics, this paper uses BP neural network to identify signature in view of its advantages of nonlinear capacity, fault tolerance and the extensive use in the classification. Therefore, the paper extracts the skeleton and four corner features, then recognize signature by using BP neural network.

BP network is a multilayer neural network, and it usually has a minimum of three layers. All the neurons in the previous layer and the next layer are fully connected, every neuron in the previous layer is connected with every neuron in the next layer. But the left layer has no connection with the right layer. The most typical BP network includes input layer, hidden layer (or intermediate layer, consisting of one layer or more layers) and output layer.

The neural network learning algorithms can be divided into supervised and unsupervised learning algorithms. In the supervised learning algorithm, input and correct output must be given at the same time, and the network will adjust itself according to the difference between the current output and the desired output. However, only a set of input should be given in the unsupervised learning algorithm, and the network can gradually evolve to make specific reaction of a certain input mode. This paper uses the supervised learning algorithm. Namely, after given the training sample and desired output
(true or false signature), the network adjusts itself by BP algorithm. This paper extracts skeleton feature and four corner feature and identifies the signature by the BP neural network.

The experiment results show the method can effectively improve the recognition speed and the correct recognition rate by combining BP neural network and Euclidean distance recognition in decision fusion. In order to validate the effectiveness of the proposed method in this paper, many groups of true and false signature images have been tested.

For multiplayer BP neural network, we must firstly confirm the number of network layers. The three or four layer network is common. In this paper, we use three layer network consisting of input layer, a hidden layer and output layer. The hidden layer is between the input layer and the output layer. There are 8 neurons in the input layer which can input the skeleton and four corner features to the neural network. The intermediate layer includes 10 neurons, and the output layer includes only 1 neuron. The output layer output the credibility, a value between 0 and 1. The value 0 indicates the forged signature and value 1 indicates real. After the network test, if the number output from the output layer is greater than the threshold of 0.5, we think the signature is true, otherwise false.

The main Matlab statement: \texttt{train (net, MatFeature, T)}. This statement means training BP neural network. The trained data, mainly containing the weight matrix between the input and hidden layer, the weight matrix between the hidden layer and output layer, and the threshold matrix of the hidden layer and output layer are stored in the net structure. BP neural network recognition results are shown in Table 1.

<table>
<thead>
<tr>
<th>The experiment images</th>
<th>Recognition accuracy rate</th>
<th>False rejection rate</th>
<th>False acceptance rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>The first group name</td>
<td>65%</td>
<td>35%</td>
<td>6%</td>
</tr>
<tr>
<td>The second group name</td>
<td>86%</td>
<td>14%</td>
<td>15%</td>
</tr>
<tr>
<td>The third group name</td>
<td>93%</td>
<td>7%</td>
<td>18%</td>
</tr>
</tbody>
</table>

There are two important statistical performance indexes in recognition system including false reject rate (FRR) and false acceptance rate (FAR). False acceptance is identifying the impostor as the real signer, false rejection means the real signer is rejected by the system. For an ideal system, both of the error rates should be zero. But in practice, these two indexes are related. When the false rejection rate is relatively lower, the false acceptance rate will be relatively higher. After observing the BP neural network recognition results in Table 1, we can conclude that BP neural network has an average correct rate of 81%.

Euclidean distance classifier adopts Euclidean distance as a measure of recognition. When get the eigenvector, the signature recognition problem becomes a typical pattern recognition problem. Using Euclidean distance classifier is comparing the eigenvector of unknown signature samples with known signature samples. Firstly, we should obtain a set of n-dimension eigenvector \( S_0 \) as standard eigenvector by a certain number of training samples. In the experiment, 10 true signature images will be separately experimented and obtain respective eigenvector. Take the average of the results to obtain the standard eigenvector \( S_0 \), \( S_0=\{S_0(i) \mid i=1,2,\ldots,n\} \), compute the test image, and obtain the Euclidean distance \( U \) between the vectors \( S \) and \( S_0 \).

\[
U = \sqrt{\sum_{i=1}^{n} (S(i) - S_0(i))^2} \quad (2)
\]

\[
R = \begin{cases} 
0 & \text{if } U > T \\
1 & \text{others} 
\end{cases} \quad (3)
\]

Where \( T \) is the threshold, and \( R=0 \) indicates the test signature recognition is false, otherwise it is matched. Minimum classifier of Euclidean distance is the fastest, because it does not calculate variance and covariance of the properties. In this paper, the edge feature of 10 true and false signatures are extracted, and then the signature threshold \( T \) is obtained. If the Euclidean distance \( U \) of the edge
features for the input signature and the true signature is greater than the distance \( T \), the signature is false. If \( U \) is smaller than \( T \), the signature is true. The recognition results of the Euclidean distance are shown in Table 2.

<table>
<thead>
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<th>The experiment images</th>
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<th>False acceptance rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>The first group name</td>
<td>75%</td>
<td>25%</td>
<td>15%</td>
</tr>
<tr>
<td>The second group name</td>
<td>71%</td>
<td>29%</td>
<td>6%</td>
</tr>
<tr>
<td>The third group name</td>
<td>100%</td>
<td>0%</td>
<td>18%</td>
</tr>
</tbody>
</table>

It can be seen from Table 2, the average correct rate is 82% using Euclidean distance method to identify signature. From the recognition results, we can see that the correct rate of BP neural network recognition and Euclidean distance recognition is less ideal. This paper introduces fusion strategy to improve the correct recognition rate.

The paper combines BP neural network and Euclidean distance recognition results in decision fusion to get the final recognition results, which improves the signature recognition accuracy. The specific steps are as follows.

1. Read and preprocess a signature image.
2. Extract the skeleton and four corner features of the signature image, and use BP neural network method to identify signature.
3. Extract the edge feature of signature image, and use Euclidean distance to identify signature.
4. Combine BP neural network and Euclidean distance recognition results in decision fusion to get the final signature recognition results. It means using OR rule to decide the BP neural network and Euclidean distance recognition result is true, in other words, as long as one of BP neural network and Euclidean distance recognition result is true, the final result is true. And using AND rule to decide the BP neural network and Euclidean distance recognition result is false, as long as both of BP neural network and Euclidean distance recognition results are true, the final result is true.

The fusion results are shown in Table 3. The fusion recognition results show the average accuracy rate of fusion method for signature recognition is 98.4%, and it increases the accuracy rate of signature recognition.

<table>
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<tbody>
<tr>
<td>The first group name</td>
<td>91%</td>
<td>9%</td>
<td>10%</td>
</tr>
<tr>
<td>The second group name</td>
<td>96%</td>
<td>4%</td>
<td>6%</td>
</tr>
<tr>
<td>The third group name</td>
<td>100%</td>
<td>0%</td>
<td>4%</td>
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</tbody>
</table>

The distance between two eigenvectors is a good similarity measure. The most simple and intuitive identification method is directly using the regions composed by the collection of various types of training sample points representing all types of the decision-making regions, and putting the distance between two points as main basis of the similarity measure, that is, the closer is distance between two points the more similar is the two samples. Many distance functions satisfied the above conditions have been proposed depending on the different applications, and Euclidean distance is common. The identification process is to compare the unknown sample feature with the known training sample feature, and determine that unknown samples are true or false. Using threshold method to determine the signature is true and false, it should give the threshold \( T \) of true and false signature. When the Euclidean distance \( U \) of edge features for the input signature and the true signature is greater than the distance \( T \), the signature is false. When \( U \) is smaller than \( T \), the signature is true. Minimum Euclidean distance classifier is the fastest, because it does not calculate variance and covariance of the properties.

The paper extracts 10 true and false signature edge features. The Euclidean distance recognition results in Table 2 show that the average accuracy rate of Euclidean distance method for signature recognition is 82%. This method has relatively lower identification rate. The key of this method is to
determine the threshold, and the threshold determination is difficult to grasp. The advantages of BP neural network recognition method include:

1. Neural network can understand less of the problem, we can model and implement by using neural network without too much domain knowledge, and identify by direct use of the spatial distribution feature for input eigenvector.

2. Neural network can achieve a more complex feature space division, namely, it can produce more complex classification curved surface.

3. Neural network shows highly nonlinear and parallel computing ability, so it appropriately uses the high-speed parallel processing system.

It can be seen neural network has unique advantage in dealing with the handwritten signature which is a complex pattern recognition problem with very complex information and certain uncertainty. However, BP neural network has its deficiencies including more training sample data, slower simulating operation, not thoroughly understand the decision-making process (e.g., not to get the decision surface of feature space).

This paper separately extracts 10 true and false signature skeleton and four corner features. It can be seen from the BP neural network recognition results in Table 1, it has an average accuracy of 81% using BP neural network for signature recognition. This method has a lower accuracy than Euclidean distance method to identify signatures, and it requires more training sample data. This paper recognizes signature in decision fusion to improve the signature recognition accuracy.

3. Conclusion

There are many feature classification in the signature recognition. This paper extracts the skeleton feature of pseudo dynamic feature, four corner feature of shape feature and the image edge feature of structure feature from the signature image. After preprocessing the signature, on one hand, extract the skeleton and the four corner features, and then give a recognition result by using BP neural network, on the other hand, extract the edge feature, and then get another recognition results by using Euclidean distance. Because information extraction is not comprehensive enough, the single identification method leads to lower recognition rate. Therefore, the paper proposes a new approach in decision fusion combing the two identification results, the method uses less data than other fusion and has a faster recognition rate. The fusion is a new idea to improve recognition rate of identity recognition and believable degree.

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5. References


546


