Research on Fingerprint Recognition Algorithm

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Abstract. Fingerprint characteristics will not change due to growth or aging, and are unique and suitable for the field of identification. The fingerprint image is scanned from left to right and from top to bottom in order to scan the points on the entire image, and then the points on the image are judged to achieve fingerprint feature point extraction. Then, the fingerprint image is preprocessed and feature extracted, and the center point of the fingerprint, the direction field of the fingerprint image and the coordinates of the feature point are obtained. The reference direction of the fingerprint is extracted. After the reference point and the reference direction of the fingerprint are determined, the characteristic information of the fingerprint is modified and the characteristic information is expressed in polar coordinates. The template and the feature information of the input image are sorted in the direction according to the direction of increasing polar angle, and the feature information is connected in series. If the matching degree of feature points is greater than the preset value, it is considered that the two fingerprints are matched successfully. It can be seen from the experimental results that the two fingerprint images are loaded, the feature point map and the smooth processing map are extracted after preprocessing, and the feature point matching degree is calculated. It can be judged that the two fingerprint images are from the same fingerprint.

1. INTRODUCTION
With the development of social science and technology, people pay more and more attention to information security. When using electronic devices such as mobile phones and computers, virtual account passwords require user identification before they can be used. Therefore, there are more and more private information on the Internet. Once the password is lost or stolen, not only personal information is leaked, but also property is easily compromised. Misappropriation. In addition, hacking technology is spreading on the Internet, and it is extremely difficult to trace the origin of this criminal technology. As a result, criminals and hackers become more and more rampant, and people or companies will be illegally invaded at all times. So we must pay attention to this problem, stop criminal behavior, and properly solve this problem, and how to correctly identify is the key task of information security. Traditional identification methods have more or less hidden security risks, which are easy to be stolen, forged, and cracked. Second, these authentication methods are easy to lose and
forget. Once the information is obtained by bad guys, it is easy to be exploited and crack the password, and it may suffer huge losses and potential risks. The fingerprint identification method has stable performance, convenience, and low cost. It has gradually become a mainstream of current identification and has a trend of gradual expansion. Everyone’s fingerprints are different [1-2].

2. Basic principles and algorithm analysis
Fingerprint image recognition requires image detection, classification, and final comparison of fingerprint images. In the process of fingerprint recognition, it is necessary to process the original image to make it have higher pixels and clearer outline, and then classify the fingerprints according to the global features, and compare the two fingerprints. The fingerprint recognition program converts the fingerprint image into a real source of information and displays it in digital form. Finally, the feature point information extracted from the two images is compared, and the similarity of the feature points is calculated to obtain the recognition result.

2.1. Basic principles of fingerprint image recognition
The lines that can be seen on the fingers are called fingerprints, and these lines are interlaced and extended on the hands. Everyone’s fingerprint is unique, and face recognition has great advantages. Fingerprint recognition has a large weight in the entire biometric position.

Fingerprint recognition can be judged by observing the global and local characteristics of the fingerprint. The global features of fingerprints refer to the features that can be seen directly, including basic lines, pattern regions and triangular points. Local features refer to the minutiae features of a small piece of fingerprint. The fingerprint is not smooth, and often splits and interrupts. The local characteristics of each fingerprint cannot be the same. British scholars proposed that by judging the coincidence of 13 fingerprint feature points, it can be determined whether two fingerprints are the same fingerprint. Through feature point extraction and matching, we can judge whether the two fingerprint images match successfully[3].

2.2. Preprocessing of fingerprint images
The R, G, and B components of each pixel of a grayscale image are the same, so each pixel has 255 ranges of variation. Using a model to explain, if the three values of R, G, and B are the same, the color represents the grayscale color, and this value is called the grayscale value. Therefore, each pixel in the grayscale image must have a byte to put the gray value (also called intensity value, brightness value), the higher the gray value, the darker the color of the point, and the range is 0-255.

Binarization is to use two values to represent the target and background of the image, with "1" representing the ridge line and "0" representing the valley line. The binary algorithm is expressed as:

\[
G_B(m, n) = \begin{cases} 
1 & G_G(m, n) \geq T \\
0 & G_G(m, n) < T 
\end{cases}
\]

\[G_G(m, n)\]—The gray value of pixel \((m, n)\) after image enhancement.

\[G_B(m, n)\]—Information in the ridge and valley lines of the image after binarization.

There are many ways to generate binary, which are mainly distinguished according to the value of T. The methods include global in-value method and local in-value method. The algorithm of the global inter-value method is relatively simple and consumes less time. However, if the fingerprint image is incomplete, uneven grayscale or large in contrast, local blurring, cut-off, and adhesion may occur after image processing, which affects the judgment result. The global inter-value method refers to dividing the entire image with speed values, such as setting non-zero pixels, binarization between constant values, binarization of point analysis, methods based on gray histograms, and so on. The global inter-value method is based on the assumption that the width of the ridge and valley in the fingerprint is basically the same. First find the gray value and use it as the intermediate value to make the ratio of black and white pixels to all fingerprints close to 1:1. The analysis method is to divide the intermediate value T of the gray value into two categories of image gray. The ratio of the average variance of the two categories to the variance of the two categories determines the value of the interval[4,5].

\[
G_B(m, n) = \begin{cases} 
1 & G_G(m, n) \geq T \\
0 & G_G(m, n) < T 
\end{cases}
\]

2
In the local inter-value method, the inter-value of each pixel is determined by its pixel and gray value. The first algorithm is dynamic inter-value addition. Cut the image into P*P small blocks. For each small block, calculate the average gray value of all pixels in the block as the inter-value of each block, and consider the gray value of each pixel in the small block. If it is greater than the middle value of the gray value, the gray pixel is 255 (white), and if it is less than the middle value of the gray value, the gray pixel is 0 (black). This method is based on the unevenness of the image and the high correlation of the gray value of the pixels in the area, and is adjusted by the brightness difference of each part of the image, thereby reducing the current status of blur, lack or adhesion in the image. The second algorithm is the dynamic inter-value method of the directional graph, which cuts the image into P*P small blocks, establishes a directional window in each small block, and binarizes the blocks by using the fingerprint's strong directivity and obvious gray-scale changes.

2.3. Fingerprint image feature point extraction algorithm

The fingerprint image feature extraction method is to scan the points on the entire fingerprint image in the order from left to right and top to bottom, and then judge the points on the image, and judge whether it is an end point or a bifurcation point from the points that meet the conditions. In terms of algorithm, the feature point extraction process is simple and easy to implement, thereby reducing the time and calculation amount of feature point extraction, and improving the accuracy of feature points[6,7].

First, find the feature points in the image, and choose a point P on the ridge line, then the sum of the adjacent inner 8 points is:

\[ SN_n(P) = \sum_{i=0}^{8} P_i (P = P_0) \] (2)

The sum of 16 points in the outer neighborhood is:

\[ SW_n(P) = \sum_{i=9}^{16} P_1 \] (3)

Equation (2) is used to find the number of effective pixels in 8 points in the area of point P, and formula (3) is used to find the number of effective pixels in 16 points in the neighborhood outside of point P, \( P_i \) represents the gray value corresponding to this point (represented by 0 or 1). Use a window of 5 × 5, take \( SN_n(P) \) as the center store, and use the value range of \( SW_n(P) \) to determine the type of feature points, as follows:

1. If \( SN_n(P) > 6 \), \( SW_n(P) < 7 \), then P becomes the end point.
2. If \( SN_n(P) < 3 \), \( SW_n(P) > 9 \), then P becomes the bifurcation point.

2.4. Feature point matching algorithm based on point pattern

Take the reference point of the fingerprint as the origin, the polar coordinate direction of the polar axis as the reference direction, and use the coordinates \((r, \theta)\) to represent the feature point coordinates \((x, y)\). The angle \( \phi \) between the polar diameter and the direction of the characteristic point is used to replace the direction \( \phi' \) of the characteristic point in Cartesian coordinates[8].

![Figure 1. Cartesian coordinate chart](image)

As shown in Figure 1, if the reference direction of the fingerprint is \( \theta_c \) and the rectangular coordinate of the reference point is \((x_c, y_c)\), then the characteristic information \((r, e, \phi)\) and \( \phi \) are respectively expressed as:

\[ r = \sqrt{(x - x_c)^2 + (y - y_c)^2} \] (4)
\[ e = \arctan 2 \frac{(y - y_c)}{(x - x_c)} - \theta_c \] (5)
\[ \phi = \phi' - e - \theta_c \] (6)
Observe Figure 1, and through the calculation of the above three formulas, it can be found that the feature information of the feature point has nothing to do with the translation of the image. Such feature representation can reduce the negative impact of the translation and rotation of the fingerprint image on the fingerprint matching algorithm. After fingerprint image preprocessing and feature extraction, the center point of the fingerprint, the orientation field of the fingerprint image and the coordinates of the feature points are obtained. Then extract the reference direction of the fingerprint. When there are two center points, the reference direction of the fingerprint is extracted according to the method of defining the reference direction mentioned above. When there is a center point, the following method is used to extract the reference direction of the fingerprint.

(1) First divide the circular area where the fingerprint center point is located into several fan-shaped small areas, and divide the circular area into \( m \times n \) fan-shaped areas. The coordinates of each small sector are represented by \((x, y)\).

(2) Calculate the directional average value \( Q_2 \) of all pixels in each sector, and the polar diameter direction \( Q \) of the midpoint of the sector, and calculate the angle \( \theta \) between the two.

\[
q(i, j) = \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} a((k)\mod(n),j)
\]

At the same time, \( A = \sin(Q) \) is used to quantify the degree of verticality between \( Q_2 \) and \( Q \), and it is regarded as the characteristic value of each small fan-shaped area.

(3) Calculate the sum of the polar diameter \( i \) and the characteristic value \( B \) of the fan-shaped area when dividing the fan-shaped area in the first step.

\[
b(i) = \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} a((k)\mod(n),j)
\]

In equation (8), the maximum value \( b(t) \) of \( B \) is calculated, and the direction of the polar diameter \( t \) is taken as the reference direction. Both fingerprint images use the fingerprint reference direction extracted by the above method. It can be found that the reference direction of the extracted fingerprint changes synchronously with the rotation of the fingerprint.

After the reference point and reference direction of the fingerprint are determined, the characteristic information of the fingerprint is modified according to formula (8), and then it becomes the characteristic information in polar coordinates. The template in the polar coordinates and the feature information of the input image are sorted in the direction according to the increasing direction of the characteristic information in polar coordinates. The template in the polar coordinates and the feature information in polar coordinates are connected into a series in the following way:

\[
\Phi = \{ (ri0, ei0, si0, \phi i0)^T, \ldots, (ri(n-1), ei(n-1), si(n-1), \phi i(n-1))^T \}
\]

\[
Wj = \{ (rj0, ej0, sj0, \phi j0)^T, \ldots, (rj(m-1), ej(m-1), sj(m-1), \phi j(m-1))^T \}
\]

Match each point in \( \Phi \) and \( Wj \), and the matching method adopts the bounding box method. The bounding box is a box placed on the detailed point of the template. A bounding box whose polar angle and polar radius changes with the change of the polar diameter of the characteristic point is adopted. If the polar diameter of the feature point is relatively large, the bounding box will have a smaller polar angle and a larger polar radius. In the image, if the feature points \( \Phi \) and \( Wj \) fall within the same bounding box, the matching is successful.

For example, the number of feature points in the two-point set are \( N_0 \) and \( M_0 \) respectively, and there are \( M_0 \) pairs of fingerprint feature points that are successfully matched in the two-point set. When \( M_0/N_0N_0 \) is greater than the preset interval \( \beta \), it is considered that the two fingerprints match successfully.

### 3. Simulation implementation

The input original image is shown in Figure 2(a), and the original image is converted to a grayscale image, as shown in Figure 2(b); after the image is binarized, it is shown in Figure 2(c). The morphological method is applied to the binary image for \( n \) times, and the operation is repeated until the image no longer changes. The output result is shown in Figure 2(d). Write the function file to find the unique point as the feature point, define a walk function, further find the feature point, define a last1 function, find no other end point or intersection around it, the image feature point extraction diagram is shown in Figure 3. From the distance function to get the line length matching, then find a point function to get the triangle side length matching, and then define \( f = \text{abs}(f11-f21)/(f11+f12) \). If the
f value is lower, the matching degree is higher. Input fingerprint image 1 and fingerprint image 2, after the two images are converted into binary images, the images are refined and feature extracted. Figure 4 shows the refinement, feature point extraction and smoothing of the two fingerprint images. It can be seen that the two fingerprint images are from the same fingerprint, indicating that the matching is successful.

(a) Original image         (b) Gray image      (c) Binarized image    (d) Refined image

Figure 2. Image preprocessing process diagram

4. Summary
With the development of society, traditional identification technology has fallen behind, and biometric identification technology continues to advance, which can be seen everywhere in life. Fingerprint recognition technology is becoming more and more popular in society. How to obtain a high degree of authenticity, speed, and algorithm is a difficult problem, especially the problem of feature point extraction and fingerprint matching of fingerprint images. This article first performs binarization and refinement processing on the collected images. Binarization can separate the background and the object, the ridges and valleys are obvious, and the image refinement can simplify the information. The fingerprint feature matching algorithm uses a point pattern-based matching algorithm, which can avoid the influence of the rotation direction of the image on the matching algorithm. But for fingerprints with severe image damage, the accuracy of the algorithm will not be so high.

(a)Fingerprint 1 thinning, feature points, smooth processing image

Figure 3. Feature point extraction image
Acknowledgment
This work was supported by the Scientific Research Project of Anhui Natural Science Research Project No. KJ2021A1165, KJ2020A0785 and the Research Team Project No.kytd201904.

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