Software Implementation Analysis of Fingerprint Identification System

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Abstract. With the fast development of E-time, the scope of Human-Computer Interaction Techniques' application has become broader and broader. At the same time, the information security and identity verification have drawn increasing attention. Fingerprint recognition technology, which has played an important role in finance, internet, medicine and security fields, develops first, and is relatively more mature in these three. This paper mainly discusses the software part of the fingerprint recognition system. The extract of fingerprint's image is directly from existing fingerprint database. Then a series of preprocessing, such as the grid, segment, smooth and converge of images, and so on, will be done. By doing these, image features could be extracted, so as to match the images of fingerprint. This paper using an implementation method, based on VC6.0 environment, in the sections of image's preprocessing and feature matching, which contains 2 easy-operation function modules.

1. Introduction

1.1. Current status of application field development
The information society is developing more and more rapidly, and mobile terminal devices have become the "protagonist" of people's lives. Some manufacturers have added fingerprint recognition technology to their mobile devices, and the wearable boom is also unfolding, and more direct man-machines. The way of interaction will have greater development prospects in the future. Fingerprint pattern recognition as an entry point will take me closer to such an area.

1.2. The Composition and Process of the Fingerprint Identification System

1.2.1. Overview of the module of the fingerprint identification system
The entire fingerprint identification system is divided into the following modules, which are relatively independent but functionally related to each other, as shown in Figure 1.1.

![Image of fingerprint identification system](image_url)

**Figure 1.1.**

(1) Fingerprint acquisition module
This module takes a static sampling and directly uses the fingerprint image in the fingerprint database for testing.
(2) Preprocessing module

The original fingerprint image is subjected to distortion correction, equalization, smoothing, etc. to complete the image realization, and a series of enhancement and refinement processes such as segmentation, denoising, enhancement, and binarization of the obtained real image are extracted, and the original fingerprint image is extracted. The feature points will eventually be compared to the data information needed to be delivered to the next module, the fingerprint pattern matching module. The processing effects of some pre-processing sub-modules are shown in Figure 1.2, 1.3, 1.4, and 1.5.

![Image 1.2: Image after equalization](image1)
![Image 1.3: Smooth processed image](image2)
![Image 1.4: Binary image processing](image3)
![Image 1.5: Image after enhancement](image4)

(3) Feature extraction module

The module mainly extracts feature values from image information. Figures 1.6 and 1.7 list two common feature points.

![Image 1.6: End of ridge feature](image5)
![Image 1.7: Line feature fork](image6)

1.2.2. Fingerprint identification system for process planning

(1) Process planning of fingerprint identification system preprocessing module

The preprocessing stage mainly completes the process of authenticating and digitizing the original image, and provides registration and comparison parameters for the matching module. Figure 1.8 shows the specific links and processes contained in the preprocessing module.
2. Matching module process planning

By comparing the center point, the triangle point, the direction field registration point and some other feature points, the result of the comprehensive comparison finally finds a match. The process is shown in Figure 1.9.

2. Fingerprint Image Preprocessing

2.1. Image distortion correction

The fingerprint image of this thesis is directly derived from the test fingerprint database, which skips the process of fingerprint collection, and mainly explains the distortion correction of the simple mathematical model.

2.1.1. Geometric correction

We subdivide the fingerprint image on a large grid of many small grids, and take the necessary linear stretching or filling for irregularities and distortions.

2.1.2. Grayscale enhancement

After geometric correction, the photon will appear brighter or darker on a certain area when imaging, which requires grayscale enhancement of the image.

2.1.3. Mathematical fitting modeling

Abstract a simple mathematical model that linearizes complex images while preserving certain error values so that we can correct and integrate the images that have been distorted.
2.2. Fingerprint Image Field and Its Calculation

2.2.1. Intensity field of fingerprint image field
The concept of image field and intensity field is introduced to visualize such physical quantities.

Set function \( f(x, y) \), let the function characterize the fingerprint image field, and the intensity field is expressed as \( V \), the gamma field amount is represented by \( |V(x, y)| = |f(x, y)| \) to describe the gray value of the pixel in the dot area.

2.2.2. The gradient field of the fingerprint image field.
In the study of fingerprint images, the fingerprint lines are classified, and the ridges and steep drops of the line trend can be recorded and characterized, and the direction of the fingerprint lines can also be recorded, so that they can be mapped to On the mathematical model, the gradient field can be calculated by performing partial differential processing on the direction vector.

Let \( \nabla(x, y, z) \) be a gradient, which can be defined as \( \left( \frac{\partial f}{\partial x}, \frac{\partial f}{\partial y}, \frac{\partial f}{\partial z} \right) \), among them:

1. Gradient operator: \( \nabla = \left( \frac{\partial}{\partial x}, \frac{\partial}{\partial y}, \frac{\partial}{\partial z} \right) \).

2. Two-dimensional image gradient field definition.

The gradient vector of the gray function \( f(x, y) \) is \( \nabla f = \left( \frac{\partial f}{\partial x}, \frac{\partial f}{\partial y} \right) \). Let the gradient field of the image be \( T(x, y) \), then \( T(x, y) = \nabla f(x, y) \).

2.3. Segmentation of Fingerprint Images
From the intensity field of the original image, a histogram of the difference between the reaction image and the background intensity can be obtained. This histogram is visually regarded as a map of the reaction gradient due to the thinning of the horizontal axis, and the part of the high gradient value is dug. Come out, this is the split.

The following formula describes a simple way to approximate the gradient magnitude: \( |T| = \sqrt{\left( \frac{\partial f}{\partial x} \right)^2 + \left( \frac{\partial f}{\partial y} \right)^2} \approx \left| \frac{\partial f}{\partial x} \right| + \left| \frac{\partial f}{\partial y} \right| \).

2.4. Balance of Fingerprint Images

2.4.1. Processing image gray balance
When the fingerprint image is processed, the original image with a larger color is equalized.

2.4.2. processing image grayscale contrast
When the fingerprint image is processed, the contrast of the image is adjusted.

2.5. Convergence of Fingerprint Images
If the pixel is too distorted or "dark", the computer cannot recognize and associate the pixel points that should be associated with it, causing the computer to "blindly recognize" the image, classifying it as a distorted image, thereby causing system error. Convergence operations on such images are required. Figure 2.3 and Figure 2.4 show the image effects before and after the convergence operation.
2.6. Smoothing of Fingerprint Images
The input of the fingerprint image sometimes brings the external light and some stains on the fingerprint into the original image. In such a case, the impression or the spot is often left on the original image, or the fingerprint line is blocked and the line appears. The faults are reflected in the intuitive sense that some places appear too sharp and rough. In order to achieve the denoising operation, a convolution operation definition is given here to mathematically describe the smoothing operation of the image.

When \( m=3 \):

\[
g(x, y) = T * f(x, y) = \sum_{i=-m}^{m} \sum_{j=-m}^{m} T(i, j) f(x-i) f(y-j)
\]

Applying the above formula to the matrix is a smoothing operation. The following describes a matrix template commonly used for smooth denoising such as edge detection, and the rectangular neighborhood of the domain average smoothing template operator (3*3 matrix).

\[
T = \frac{1}{9} \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}
\]

2.7. Enhancement of Fingerprint Images

2.7.1. Gabor wavelet definition
The Gabor wavelet function consists of a Gaussian function and a trigonometric function, forming a function of periodic oscillation.

The one-dimensional expression of the Gabor wavelet function is:

\[
H(x) = \frac{1}{\sqrt{2\pi}\sigma} \exp\left( -\frac{x^2}{2\sigma^2} \right) \cos(2\pi fx)
\]

The two-dimensional expression of the Gabor wavelet function is:

\[
II(x, y) = G(x', y') \exp(2\pi fx' i)
\]

The formula is specified as follows.

1) Gaussian component:
(2) The rotation formula of the coordinate axis:

\[
\begin{bmatrix}
 x' \\
 y'
\end{bmatrix} =
\begin{bmatrix}
 \cos(90° - \theta) & \sin(90° - \theta) \\
 -\sin(90° - \theta) & \cos(90° - \theta)
\end{bmatrix}
\begin{bmatrix}
 x \\
 y
\end{bmatrix} =
\begin{bmatrix}
 \sin\theta & \cos\theta \\
 -\cos\theta & \sin\theta
\end{bmatrix}
\]

(3) Parameter Description.

f is the frequency.

\( \sigma \) is the standard deviation.

\( \gamma \) refers to the ratio of the long and short axes of the ellipse below the image.

\( \theta \) refers to the angle formed by the positive direction of the x-axis.

3. Feature Matching of Fingerprint Images

3.1. Fingerprint Feature Extraction

The extraction of singular points of fingerprint features mainly takes two steps.

1. Poincare calculations.

2. Calculate the final singularity by averaging.

We get a few of the surrounding singularities we get by averaging. False singularities may occur due to noise or other effects in some fingerprint images.

The multi-directional matrix parameter table implemented according to this algorithm is given below, with i, j as the center, and the direction vector parameter values of the surrounding directions are as shown in Table 3.1.

Table 3.1. Mean value of direction field of singular point 5*5

|   | 3 | 2 | 1 |
|---|---|---|---|
| 4 | 3 | 2 | 1  |
| 5 | 4 | (i, j) | 8 |
| 6 | 5 | 6 | 7  |
|   | 7 | 8 | 9  |

3.2. Registration and Matching of Fingerprint Images

3.2.1. Registration method of fingerprint image

(1) Special point method.

Look for the special position of the fingerprint image. The most common ones are the center point and the triangle point. Compare the multiple pairs of special points one by one to determine whether the registration is successful.

3.2.2. Matching of fingerprint images

The matching of the fingerprint image has been gradually transformed into the implementation of the algorithm, which involves the realization of the algorithm.

The first thing to consider is that the algorithm implementation flow chart is shown in Figure 3.1.
Comparing P with P', if the prior feature template is satisfied, that is, P is approximately equal to P', and within the error value, then the match can be determined, so that the match of the array P and P' can determine that the match is successful.

3.3. Test Results and Demonstration

3.3.1. Preprocessing module
By selecting a fingerprint image, it performs various detail processing and feature extraction in the preprocessing stage, thus providing reference data for the matching module. The test interface is shown in Figure 3.2.

3.3.2. Matching module
The data obtained from the preprocessing module implements matching of two fingerprint images in this function module, and the operation interface is as shown in Figure 3.3.
4. References

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