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Orientation Estimation Method Based on Directional Gradient

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Abstract: *In fingerprint recognition system, fingerprint features must be extracted. Fingerprint preprocessing is the premise of fingerprint feature extraction, which can improve the effect of feature extraction. This paper introduces the orientation estimation method based on the direction gradient, and applies this method to improve the effect of fingerprint image preprocessing. Experimental results show the effectiveness of this method.*

Keywords: *orientation, computation of the orientation, preprocessing*

1. Introduction

Fingerprint recognition is an important branch in the field of digital image processing and pattern recognition, and also a challenging subject. The application of fingerprint automatic identification system can replace the traditional methods of password, identification card, private seal, etc. to identify personal identity. At present, it has been successfully applied in public security case analysis, factory attendance system, bank savings system, registered residence management system At home and abroad, fingerprint recognition technology based on detail feature points is mostly adopted, that is, fingerprint recognition algorithms based on image processing, and there are two representative ones. One is an algorithm based on directional filtering enhancement and extracting feature points from fingerprint thinning images, while the other is an algorithm that directly extracts feature points from fingerprint grayscale images. The challenge lies in the fact that some algorithms may experience errors during the recognition process due to various factors such as noise in fingerprint images and nonlinear deformation caused by skin elasticity, which can affect recognition rates. [1]

Orientation is a fundamental feature that distinguishes multidimensional signals from one-dimensional signals [2], and orientation estimation plays an important role in image processing and machine vision. In addition, the local orientation information of an image is an important local feature that can significantly improve the performance of image processing algorithms. Reference [2] provides a comprehensive description of the relevant work and principles of orientation estimation.

This paper applies orientation estimation based on directional gradient to preprocess the fingerprint images, in order to refine and extract features in the subsequent steps by combining the orientation information of each point. The main content of this article is arranged as follows: Section 2 gives a method description; The third section showa the experimental results and analysis, and then is the conclusion.

2. The algorithm framework

We only accept papers written in English and without orthographic errors.

The general process of fingerprint image preprocessing is:

1) Image normalization, which specifies the mean and variance of image grayscale within a certain range;

2) Image segmentation, separating effective regions;

3) Image enhancement to improve image contrast;

4) Binarization;

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5) Refine the image to obtain a single pixel curve of the fingerprint texture.

To further improve image quality, this article adds the step of orientation estimation after image refinement to obtain the orientation of each point, and further processes the image using orientation information.

The basic principle of orientation estimation algorithm based on directional gradient is introduced below.

To overcome the discontinuity of tangent transformation near 90 degrees and the periodicity of trigonometric functions and angles, Kass and Witkin proposed a good solution [3]. The basic idea is to calculate the double angle:

$$d_{ij} = [r_{ij} \cdot \cos 2\theta_{ij}, r_{ij} \cdot \sin 2\theta_{ij}] \text{ , } \theta_{ij} = \arctan(\nabla_y / \nabla_x) \tag{1}$$

Where dij represents the orientation vector of the i-th row and j-th column in the image, rijIs a unit vector perpendicular to the orientation axis, θij is the orientaiton angle,▽y and ▽x denote the gradient of y and x.To further improve robustness, neighborhood smoothing estimation results are taken:

$$\overline{d} = [\frac{1}{n^2}\sum_{i,j} r_{ij} \cdot \cos 2\theta_{ij}, \frac{1}{n^2}\sum_{i,j} r_{ij} \cdot \sin 2\theta_{ij}] \tag{2}$$

In equation (2), the meanings of each symbol are the same as in equation (1), but they become the mean. Based on the above ideas, it can be further estimated by equation (3):

$$\theta_{ij} = 90^\circ + \tfrac{1}{2}\arctan\left(\frac{2G_{xy}}{G_{xx} - G_{yy}}\right) \tag{3}$$

Where

$$G_{xy} = \sum_{h=-8}^{8}\sum_{k=-8}^{8} \nabla_x(x_i + h, y_j + k) \cdot \nabla_y(x_i + h, y_j + k)$$
$$G_{xx} = \sum_{h=-8}^{8}\sum_{k=-8}^{8} \nabla_x(x_i + h, y_j + k) \cdot \nabla_x(x_i + h, y_j + k)$$
$$G_{yy} = \sum_{h=-8}^{8}\sum_{k=-8}^{8} \nabla_y(x_i + h, y_j + k) \cdot \nabla_y(x_i + h, y_j + k)$$

Among them, the grayscale gradient is calculated using 3 × 3 Sobel operator calculation.

Given that the main drawback of gradient based methods is their poor robustness to noise, they often require an overall smoothing process [4], which causes local features of orientation estimation to be disturbed by global features. A small improvement has been made in this article: rough estimation is made by taking 8 neighborhoods first, and then refinement is carried out to achieve a balance between estimation accuracy and computational complexity.

3. Experimental results and analysis

3.1. On test images

Firstly the algorithm is applied to an image containing several curves with different radians. Examples of experimental results are shown in Figure 1, Figure 2 and Figure 3. In each figure, Figure (a) shows the images pre-processed in the first three steps, Figure (b) shows the direct refinement results, and Figure (c) shows the refinement results after adding orientation estimation. From it, it can be seen that adding orientation estimation based on directional filtering can obtain more continuous and clearer refined images.

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(a) (b) (c)

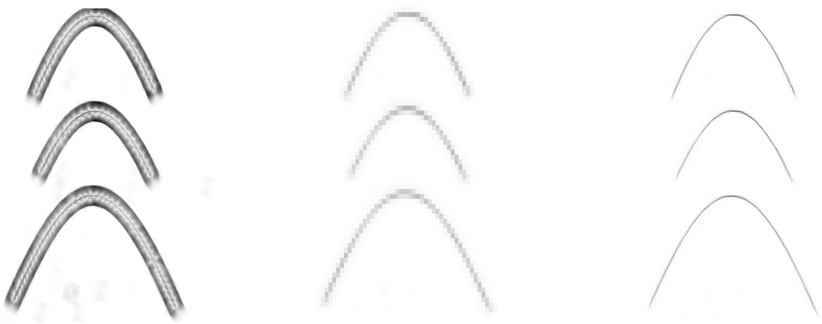
(a) Preprocessed image (b) direct thinning result (c) thinning result after adding orientation estimation

Figure 1: Example 1 of curve Image Experiment Results

(a) (b) (c)

(a) Preprocessed image (b) direct thinning result (c) thinning result after adding orientation estimation.

Figure 2: Example 2 of curve Image Experiment Results



(a) (b) (c)

(a) Preprocessed image (b) direct thinning result (c) thinning result after adding orientation estimation.

Figure 3: Example 3 of curve Image Experiment Results

3.2. On Fingerprint images

This article uses the Secugen fingerprint acquisition instrument to collect images, with a unified image size of 256 x 256. The experiment is conducted using Matlab on a machine configured with CPU Sagittarius II X4, motherboard MSI 880GM-E41, and memory 2GB DDR3. Examples of experimental results are shown in Figure 4 Figure 5. In each figure, Figure (a) shows the images pre-processed in the first three steps, Figure (b) shows the direct refinement results, and Figure (c) shows the refinement results after adding orientation estimation. From it, it can be seen that adding orientation estimation based on directional filtering can obtain more continuous and clearer refined images.

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(a) (b) (c)

(a) Preprocessed image (b) direct thinning result (c) thinning result after adding orientation estimation

Figure 4: Example 1 of Fingerprint Image Experiment Results

(a) (b) (c)

(a) Preprocessed image (b) direct thinning result (c) thinning result after adding orientation estimation

Figure 5: Example 2 of Fingerprint Image Experiment Results

4. Conclusions

This article applies orientation estimation based on directional gradient to the preprocessing process of fingerprint images, in order to refine and extract features in the subsequent steps by combining the orientation information of each point. The experimental results demonstrate the effectiveness of the algorithm. In future research, we will improve the existing methods for analyzing grayscale gradients [5, 6], as correctly calculating the gradients of discrete signals is inherently a challenging problem, and it is not appropriate to use gradients calculated through intermediate processes. The calculation results (estimated orientation angles) must be optimized.

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