Fingerprint Ridge Orientation Estimation Using A Modified Canny Edge Detection Mask

Laurice Phillips
PhD student
laurice.phillips@utt.edu.tt

Margaret Bernard
Senior Lecturer and Head of Department
Margaret.Bernard@sta.uwi.edu

ABSTRACT

Fingerprint recognition is arguably the most popular biometric used in authentication of individuals today. One critical step in the process of automatic fingerprint recognition is the segmentation of a digital fingerprint image into smaller regions where local image features can be more easily enhanced, analyzed or extracted. In this process it is essential to accurately estimate the fingerprint ridge orientation within the local region so that the fingerprint's core singular points can be identified. This research paper proposes a novel approach to estimating the local ridge orientation by using an image convolution operation based on a Canny Edge detection mask. Experimental results illustrate the effectiveness of the algorithm in establishing the dominant edge direction of the ridge.

Keywords

Segmentation, Canny Edge Detection Mask, Edge direction, Segment Orientation

INTRODUCTION

The success of any Automatic Fingerprint Identification System depends on several important pre-recognition steps. These steps involve image pre-processing, fingerprint image enhancement, segmentation as well as the identification of regions within the image where core features and characteristics, used in the recognition phase, are located. One of the most important features that must be estimated is the local ridge orientation or direction within the fingerprint image. This estimation is crucial to identifying the major core singular characteristics of the fingerprint image. Core singularities include features such as Whorls, Deltas, Arches and Loops. The identification of such structures within the image aids the efficiency of the recognition process of fingerprint images and fingerprint templates in any Automatic Fingerprint Information System (AFIS) system. Canny (1986) introduced an edge detection algorithm for digital images using a Gaussian spatial filter. This has become well known and is considered an optimal edge detector. In this paper, we propose a novel approach to estimating the local ridge orientation by using an image convolution operation based on a Canny Edge detection mask. Preliminary experimental results show good performance of the algorithm in establishing the dominant edge direction of the ridge.

In section 1.1 of this paper we present some of the literature related to fingerprint ridge orientation estimation. In Section 2, we review the segmentation of the image and the Canny Edge Detection algorithm. In section 3, we describe our improved Edge Detection algorithm with some

Prior Related Work

Hong, Wan, and Jain (1998) introduced the use of Gabor filters in the process of image enhancement. Their research showed that Gabor filters have both frequency and directional properties. Since then a number of research papers have been published giving improved and modified versions of the Gabor filters for fingerprint image enhancement, including Yang, Liu, Jiang and fan (2003) and Wang, Jianwei, Huang, and Feng (2008). .

Research done by Greenberg, Aladjem, Kogan, and Dimitov (2002) developed fingerprint image enhancement using filtering techniques. These techniques require both pre and post processing and involve methods such as Histogram equalization, Wiener filtering and Anisotropic filtering.

Zhu, Yen and Zhang (2005) proposed a scheme for systematically estimating fingerprint ridge orientation of segmentation by using a neural network based algorithm. They proposed that a neural network can be used to learn the correctness of estimated ridge orientation by gradient-based methods.

Liu and Dai (2006), proposed a ridge orientation estimation and verification algorithm that uses a K-Slope method to capture the ridge curvature while reducing the effects from noise pixels. Their research showed the application of both isotropic and anisotropic filters on selected regions.

Phillips (2007) introduced an approach to segmentation of the fingerprint image and applied a Sobel mask to enhance the contrast in the pattern of ridges and valleys.

Luping and Zhang (2008), proposed a fingerprint orientation field estimation with ridge projection. Their research proposed a Pulsed Coupled Neural Network method with block direction estimation by projective distance variation.

Ram, Bischof, and Birchbauer (2009), proposed a statistical model for fingerprint ridge orientations that uses an active fingerprint ridge model that iteratively deforms to fit the ridge orientation of the fingerprint. This technique uses operates with a fully automated training set that does not need user intervention.

IMAGE SEGMENTATION

The proposed algorithm requires that a digital fingerprint image be segmented. This segmentation process is part of a general image pre-processing step that is used to enhance the underlying ridge and valley patterns within the fingerprint image.

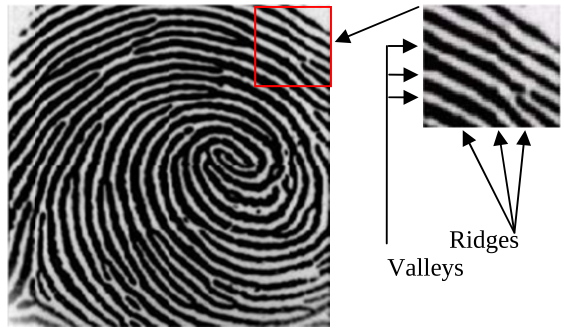


Figure 1: Snapshot of a digital fingerprint image highlighting the inherent ridges and valleys.

The image below shows the fingerprint image which has been segmented with a local region of 10 X 10 pixels.

Segmented Binary Image

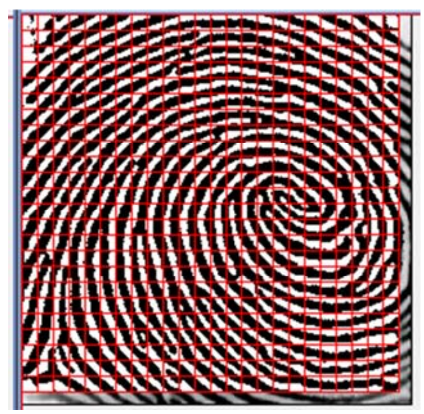


Figure 2: Segmented image superimposed over the enhanced normalized image.

Each image segment highlights a local region within the digital image that is used to isolate the local ridge and valley patterns within the image. This region illustrates the binarized pixel patterns of the 10 x 10 region of interest. The image segmentation algorithm also captures the local statistics of the highlighted region such as the mean, variance and standard deviation.

Sample segmented fingerprint image region
Image Region: [x,y,w,h] [80,80,10,10] Mean, Var, Stadev: [M,V,S] [102,15606,124.924] Edge Dir: [45]

255	255	255	255	255	255	255	0	0	0
255	255	255	255	255	255	0	0	0	0
255	255	255	255	255	0	0	0	0	0
255	255	255	255	0	0	0	0	0	0
255	255	255	0	0	0	0	0	0	0
255	0	0	0	0	0	0	0	0	255
0	0	0	0	0	0	0	0	255	255
0	0	0	0	0	0	0	255	255	255
0	0	0	0	0	0	255	255	255	255
0	0	0	0	0	0	255	255	255	255

Table 1: Snapshot of image pixel intensities for a selected segment.

Edge Detection

The purpose of edge detection in digital images is to identify the boundaries of objects. These boundaries are highlighted by a sharp change in the image pixel intensities. Spatial 2D convolution filters can apply a gradient based measurement to identify the edge of the object's boundary as well as estimate the edges direction.

The Canny edge detection algorithm is well known as an optimal edge detector in digital images (Canny, J, 1986). The implementation of the Canny algorithm is done in several steps. Firstly, the fingerprint image must be filtered from noise to reduce or eliminate the detection of false edges. Canny used a Gaussian filter in this process to smooth or blur the image, thereby, mitigating certain undesirable features or noise. The Gaussian filter can be implemented with a spatial 2D filter.

The Canny Edge detection mask uses a Gaussian spatial filter to blur the fingerprint image in an attempt to mitigate some of the subtle noise within the image. The process also allows ridge patterns with stronger or more prominent edges to become highlighted.

The Canny mask, see table below uses a 2D spatial gradient measurement of the image in the X and Y directions. The gradient measurement is based on two convolution mask operations.

Canny Edge Detection Masks

-1	-1
1	1

GX

-1	1
-1	1

GY

Table 2: Illustration of Canny Masks.

The gradient operation returns edge strengths or magnitudes in the X direction, GX and in the Y direction called GY.

Edge Strength,

$$|G| = |GX| + |GY| \qquad \textit{Eqn } 1$$

Once the gradient measures Gx and Gy are obtained then the edge direction, can be derived from the formula:

$$\phi = \tan^{-1}\left({Gx}/{Gy} \right) \qquad \textit{Eqn } 2$$

The edge detection masks highlighted, table 1, illustrates the detection of a single edge point in the image.

PROPOSED ALGORITHM

This research paper proposes a modification to the above strategy by extending the edge masks to encompass the segmented region of interest. See table 2.

The initial region has been segmented by a 10 x 10 pixel section. This is further subdivided into 4 sub regions of size 5 x 5 pixels. The modified Canny Mask is extended over the sub region and the edge strengths are calculated.

An edge direction is calculated for each sub-region using the formula in equations 1 and 2.

-1	-1	-1	-1	-1
-1	-1	-1	-1	-1
0	0	0	0	0
1	1	1	1	1
1	1	1	1	1

Table 3a: GX Extended Edge Masks.

-1	-1	0	1	1
-1	-1	0	1	1
-1	-1	0	1	1
-1	-1	0	1	1
-1	-1	0	1	1

Table 3b: GY Extended Edge Masks.

This process generates 4 angles representing the edge directions of each of the four sub-regions highlighted in table 5

Segment Detection

The dominant edge direction can be extracted by use of a fast comparison and averaging approach. The approach is outlined as follows:

For each of the directions established, angles are compared and then dominant angle is computed. The minimum difference is established. The minimum pair is then selected and the average is computed. This average represents the dominant edge orientation for the specified segmented region.

255	255	255	255	255
255	255	255	255	255
255	255	255	255	255
255	255	255	255	0
255	255	255	0	0

Table 4a: Segmented sub region 1.

255	255	0	0	0
255	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0

Table 4b: Segmented sub region 2.

255	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0

Table 4c: Segmented sub region 3.

0	0	0	0	255
0	0	0	255	255
0	0	255	255	255
0	255	255	255	255
0	255	255	255	255

Table 4d: Segmented sub region 4.

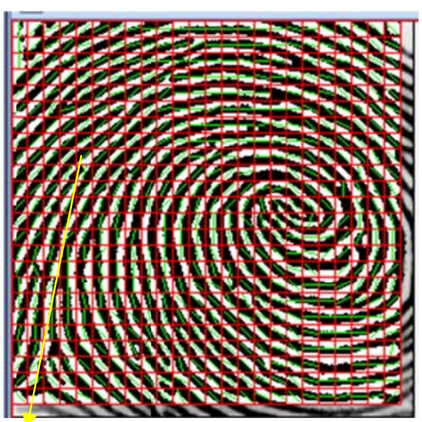
Sub Region Ridge Orientation Angle	
45	45
45	35.5
GX	GY

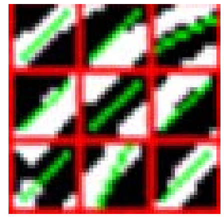
Table 5: Segmented sub region angles.

Edge Orientation Selection	
45	45
45	35.5
GX	GY

Table 6: Segmented sub angle comparison.

Figure 3 illustrates the results of the algorithm, proposed in this research, on a sample digital figure print image. The snapshot image reveals the alignment of the estimated ridge orientation flow superimposed on the underlying ridge pattern.





Snapshot of selected segment showing dominant edge direction together with fingerprint ridge flow

Figure 3: Segmented Oriented Edge Flow image superimposed original image.

REFERENCES

1. Canny, J., (1986), A Computational Approach To Edge Detection, IEEE Trans. Pattern Analysis and Machine Intelligence, Vol. 8, No.6, 679–698

2. Greenberg, S., Aladjem M., Kogan, D., and Dimitrov, I., (2000) Fingerprint Image Enhancemet using Filtering Techniques, Real-Time Imaging, Vol 8, No.3, 227 - 236

3. Hong, L., Wan, Y., and Jain, A.K., (1998), Fingerprint Image Enhancement: Algorithms and Performance Evaluation, IEEE Trans. Pattern Analysis Machine Intelligent, Vol. 20, No. 8, 777-789

4. Liu, L., and Dai,T., (2006), Ridge Orientation Estimation and Verification Algorithm for Fingerprint Enhancement, Journal of Universal Computer Science, Vol. 12, No. 10, 1426-1438

5. Luping, J., and Zhang, Y., (2008), Fingerprint Orientation Field Estimation using Ridge Projection, Pattern Recognition, Vol. 41, No. 5, 1491 – 1503

6. Maltoni, D., Maio, D., and Jain, A.K., (2003). Handbook of Fingerprint Matching and Recognition: Springer 2009

7. Phillips, L., (2007), An Approach to Fingerprint Analysis, Feature Extraction and Pattern Matching, MSc. Thesis, The University of the West Indies, Trinidad

8. Ram,S., Bischof, H., and Birchbauer, J., (2009), Active Fingerprint Ridge Orientation Models, Lecture Notes in Computer Science, Vol. 5558, 534 - 543

9. Wang, W., Jianwei, L., Huang, F., and Feng, H., (2008), Design and Implementation of Log-Gabor Filter in Fingerprint Image Enhancement. Pattern Recognition Letters, Vol. 29, No. 3, 301 - 308

10. Yang, J., Liu, L., Jiang, T., and Fan, Y., (2003), A Modified Gabor Filter Design Method for Fingerprint Image Enhancement, Pattern Recognition LettersVol. 24, 1805 - 1817

11. Zhu, E., Yin, J.P. and Zhang, G.M., (2005) Fingerprint Matching based on Global Alignment of Multiple Reference Minutiae. Pattern Recognition Letters, Vol. 38 No.10, 1685-1694.

ACKNOWLEDGEMENTS

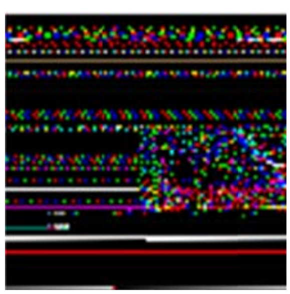
Special thanks to Dr. Margaret Bernard for her continued support, inspiration and encouragement.

APPENDIX

Sample fingerprint image.

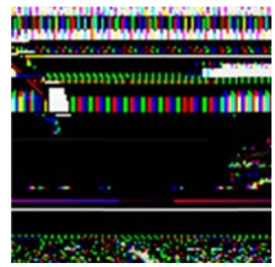
Segmented fingerprint image with edge orientation flow.

Sample fingerprint image.



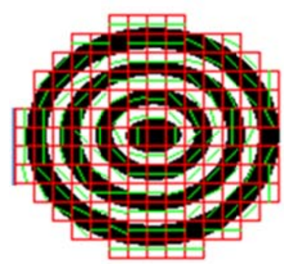
Segmented fingerprint image with edge orientation flow.

Sample synthetic Image.



Segmented synthetic image with edge orientation flow.

Sample synthetic Image.



Segmented synthetic image with edge orientation flow.