A novel Auto-adaptive Fingerprint Capture System Based on Image Quality Evaluation Algorithm

H.Huang,J.W. Li and W. He

Key Lab. on Opto-electronic Technique and systems, Ministry of Education

Chongqing University
400030 Chongqing, China

Abstract **- A design of the fingerprint capture system based on chip FPS200 is introduced. The capture system uses the MCU interface with DSP. In this paper, a new method based on the intrinsic directional features of fingerprint is proposed to evaluate the quality of images acquired by FPS200 sensor. Using directional map, the available area of image and clearness is checked to calculate the overall image quality score that can be used to quantitatively determine the quality of the fingerprint image. If the quality of image is unsatisfied, prompt is presented: whether the finger is wet or dry, then DSP adjusts the parameters of FPS200 sensor automatically until image of good quality has been acquired. Experimental results show that the image capture system and the corresponding algorithm can be integrated into practical embedded Automatic Fingerprint Identification System.**

I. INTRODUCTION

Automatic Fingerprint Identification System (AFIS) is becoming more popular in security access and E-commerce applications. An AFIS is an integrated system that can handle fingerprint registration as well as identification with minimum attention. However, the identification performance of such system is very sensitive to the quality of the captured fingerprint image. Since AFIS is expected to work independently, exposed to potentially a large number of users, the fingerprint sensor that is attached to the system is possibly subjected to impropriate use. This includes the applying of one's finger that is dry, wet as shown in Figure 1. Poor quality image causes AFIS to have higher operation problems such as false acceptance and false rejection; resulting in the user facing difficulties when using AFIS for identification.

(a) Image of wet finger (b) Image of dry finger

Fig. 1 Examples of low quality Fingerprint image

Previous related literatures can be found in various publications. Hong et a1 [1] used sine wave to model the ridge and valley pattern of the fingerprint. Shen et al [2] used gabor filler to every image sub-blocks with assumption that a good fingerprint can be recognized by the outputs of a gabor filter hank. Both of these methods exploited to measure the quality of the image. However, what contribute to the bad quality of fingerprint images and how to acquire images of good quality? They haven't been touched upon.

Hence, in this paper, we propose a new method to justify the quality of the fingerprint image for the authentication system. The proposed scheme can be used to detect poor quality fingerprint image for the AFIS.

The paper is organized as shows. The FPS200 sensor and the fingerprint capture system is briefly introduced in Section 2.In Section 3, the proposed quality evaluation algorithm is presented. The results based on the proposed algorithm are discussed in Section 4 and conclusions describe in Section 5.

II. FPS200 AND FINGERPRINT CAPTURE SYSTEM

The fingerprint capture system consists of FPS200 sensor and DSP. The system can acquire fingerprint image without the help of PC.

Veridicom's robust FPS200 solid-state, 500 dpi fingerprint sensor is an ideal direct-contact fingerprint acquisition device. The chip's 256×300 array and thin package provide a space-saving, cost effective image area. Designed for embedded devices,this high-performance, low-power, low-cost capacitive sensor is easy to integrate into embedded appliances.

The FPS200 is the first fingerprint sensing device to incorporate three modes of communication: USB, MCU, and SPI. This makes the sensor easy to integrate into DSP without requiring external interface devices. FPS200 sensor uses the MCU interface with DSP as shown in Figure 2.

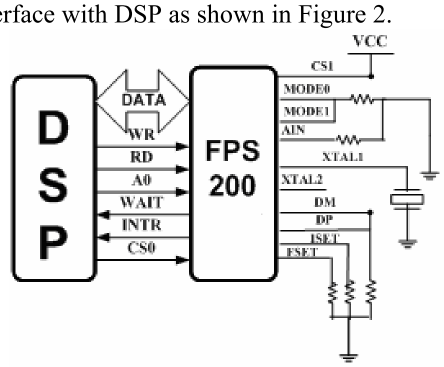


Fig. 2 Hardware design of Fingerprint Acquisition System

The sensitivity of the chip is adjusted by changing the discharge current and discharge time. The current source is controlled from the Discharge Current Register (DCR). The discharge time is controlled by the Discharge Time Register (DTR). The contrast of fingerprint image is controlled by the Programmable Gain Control Register (PGC).If an image which was captured from FPS200 with the default values of the registers is of poor quality, DSP can adjust the values of the registers automatically through software until image of good quality has been captured as shown in Figure 3.

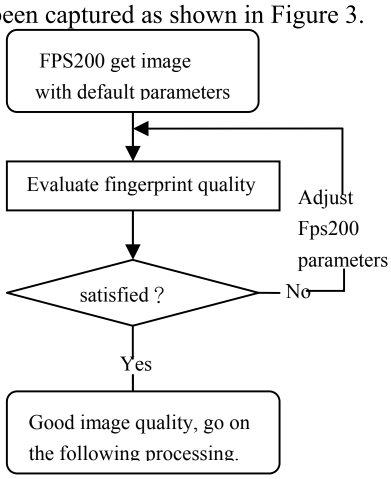


Fig. 3 Flow chart of FPS200 parameters adjusting

III. Assessing Fingerprint Quality

In the process of assessing Fingerprint Quality, all the work should be done by DSP. In order to lessen the burden of DSP, the quality analysis uses a sub-sampled image. The analysis samples the image at rate in *x* and *y*-directions. The sub-sampled image is further divided into square blocks of different sizes B. The experimental result shows that the sub-sampling image doesn't affect the performance of algorithm.

A. *Direction and foreground estimation*

This step determines if a given block depicts a portion of a fingerprint and extracts a nominal direction from a foreground block. Any number of existing strategies can be adopted [1,3,4]. For efficiency reasons, we use the method proposed by Mehtre [5]. At each pixel in a given block, a number of pixels are selected along a line segment of an orientation (d) and pre-specified length (l) centered around that pixel; variation in the intensities of the selected pixels is then determined by computing the sum of intensity differences $D_d(i,j)$ between the given pixel and the selected pixels,

$$D_d(i,j)=\sum_{(i',j')} |f(i,j)-f_d(i',j')| \quad (1)$$

with d = 0,π/n,…, πand where *f(i,j)* is the intensity of $\tilde{d}$ and $f_d(i',j')$are the intensities of the neighbors of along direction d. This indicates the summation of differences between the given pixel of interest, *pixel(i,j)*,, and a number l neighboring pixels along each of the directions. The variation in intensities is computed for n discrete orientations; the orientation at a pixel $\tilde{d}$ is the orientation of the line segment for which the intensity variation thus computed is minimal.

Regions of background and portions of impressions having faint residual leftover of earlier captured prints on a dirty input device usually exhibit small intensity variation around their neighborhoods. To determine if an image pixel belongs to the background, the intensity variation *D(i,j)*at the *pixel(i,j)* of interest is subsequently obtained by summing up the differences in the *n* directions with $D(i,j)=\sum_d D_d(i,j)$ and when *D* is less than a background threshold *T* for each d, the pixel is classified as a background pixel. When more than a fraction of pixels in a block are background pixels, the block is regarded as background block.

Using connected component analysis, foreground components that are smaller than a certain threshold fraction of the total image area T_3 are considered spurious. A fingerprint with no legitimate foreground area is of poorest quality.

B. *Dominant direction*

After the foreground blocks are marked, it is determined if the resulting direction for each block is prominent. The idea is that a block with a prominent direction should exhibit a clear ridge/valley direction that is consistent with most of the pixel directions in the block. Existence of a dominant direction can be assessed by computing a histogram of directions D_d (1) at each pixel in a given block. If the maximum value of the histogram is greater than a prominent threshold T_1 the block is said to have a dominant direction, and is labeled as prominent. Bifurcations of ridges may often result in two dominant directions in a block. Therefore, if two or more directions of the direction histogram are greater than a bifurcation threshold, $T_2<T_1$, he corresponding block is labeled as such. A post-processing step removes blocks that are inconsistent with their neighbors. If a "directional" block is surrounded by "non-directional" blocks, it is relabeled as a non-directional block. Similarly, a non-directional block surrounded by neighboring directional blocks is changed to a directional block. Using connected component analysis, finally, regions of dominant blocks with area smaller than a threshold number of blocks *β* are discarded. The result is that the fingerprint foreground image is partitioned into (i) regions of contiguous blocks with direction and (ii) regions of blocks without direction or non-contiguous blocks with direction.

C. *Quality computation*

Since regions (or accordingly minutiae) near the centroid are likely to provide more information for biometrics authentication, the overall quality of the fingerprint image is computed from the directional blocks by assigning relative weight w_i for foreground block i at location x_i given by

$$w_i = \exp\{-\|x_i - x_c\|^2/(2q^2)\} \quad (2)$$

where x_c is the centroid of foreground, and *q* is a normalization constant. The overall quality *Q* of a fingerprint image is obtained by computing the ratio of total weights of directional blocks to the total weights for each of the blocks in the foreground, $Q=\sum_D W_i/\sum_F W_i$. Here D is the set of directional blocks and F the set of foreground blocks. The quality Q is used as a measure of how much reliable directional information is available in a fingerprint image. If the computed Q is less than the quality threshold, T, the image is considered to be of poor quality.

D. Dryness and wetness

Once it is determined that the fingerprint is of a certain poor quality, it is desirable to be able to identify a more specific cause of the low quality. We describe a method of distinguishing wet poor quality prints from dry poor quality prints based on simple statistical pixel intensity based features. The idea is that for a wet impression, there are a relatively large number of blocks whose contrast is very small. Similarly, for a dry impression, there are a relatively large number of blocks where the contrasts of their neighbors vary significantly.

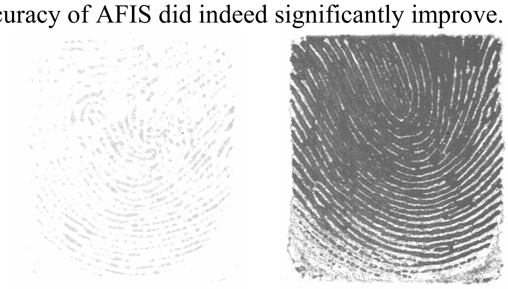
First, the mean intensity of pixels within each foreground block is computed. The pixels whose intensities are smaller than the mean intensity of all the pixels in the block are considered pixels on a ridge, i.e., ridge pixels. Let μ be the true mean intensity of ridge pixels. For each block, the mean intensity (μ) is estimated using pixels whose intensities are smaller than the mean intensity of all pixels within the block. Further, the standard deviation (σ) of intensities of all pixels within the same block is determined. For a block with good contrast, μ is small and σ is large; for a block with low contrast due to moistness μ is small and σ is small. The contrast within a block is measured using the product ($c_s= \mu\sigma$). If the contrast measure c_s is smaller than a thresholdρ_1, the block is classified as a moistened block. Lastly, the moistness measure is determined as the ratio of the number of moistened blocks to total number of foreground blocks. If the resulting ratio is larger than a threshold,ρ_2,a moistened impression is reported.

For a block with good contrast, on the other hand, μ is small and σ is large. For a block with low contrast due to dryness, however, μ is large and σ is small. Consequently, to measure the contrast within a block, we compute the ratio of corresponding μ to corresponding σ, i.e., $c_d= \mu/\sigma$ where c_d is the contrast measure. A block is considered to be dry if c_d is greater than a dryness threshold,δ_1.Alternatively, the fingerprint is considered dry if the contrasts of its neighboring blocks vary significantly. Specifically, let the c_{max} (c_{min}) be maximum (minimum) value of contrast difference between the contrast of the given block and those of its neighboring blocks. If the difference between c_{max} and c_{min} is larger than a dryness thresholdδ_2, then the block is a dry block. The dryness measure of the image is computed as the ratio of the total number of dry blocks to the total number of foreground blocks. If the resulting measure is greater than a threshold, $\delta 3$, it is reported that a dry impression causes the quality problems.

IV. Experimental Results

The capture system and the algorithm has been implemented and tested on a large number of people. The system and algorithms are extremely fast (e.g. less than 500ms on a 160 MHz DSP TMSVC5416).Typical operational parameters for the FPS200 and the proposed quality assessment algorithm for and 8-bit, 500 dpi 256×300 gray scale images are: *s=2 and B=7, DTR=0x30, DCR=0x02.PGC=0x0A*.Figure 4 illustrates results of the quality assessment of the original images with default parameters of FPS200. Figure 5 shows results of the quality assessment of the images acquired through the corresponding parameters adjusting.

From Figure 5, in contrast to Figure 4, the quality of images improves greatly. The results of the quality assessment typically appear consistent with visual human assessment. The fingerprint capture system and the evaluation algorithm have been integrated into practical embedded AFIS. As expected, the accuracy of AFIS did indeed significantly improve.



(a)Quality= (0.2, 0.0, 0.7) (b) Quality= (0.3, 0.6, 0.0)

Fig.4 A fingerprints quality assessment measure.

Quality(x,y,z)indicates print of overall quality x,moistness y,and dryness z.

(a)Quality= (0.8, 0.0, 0.1) (b) Quality= (0.7, 0.2, 0.0)

Fig. 5 A fingerprint quality assessment measure through the parameters adjusting.

V. Conclusions

Automatically and consistently determining suitability of a given input measurement (biometrics sample) for automatic identification is a challenging problem. This paper proposes a method of the evaluation of fingerprint quality and a system of an auto-adapt fingerprint image acquisition based on the corresponding results of categorizing a poor quality fingerprint into either dry or wet prints. Currently, we notice that the value of threshold is crucial to the accuracy of algorithms, so we are examining the possibility of image evaluation based on the auto-select threshold. We are also exploring generic description of image quality in other domains such as faces, irises, etc.

Acknowledgment

My heart-felt gratitude first goes to Professor Li Jianwei, my supervisor, for his insightful advice in my paper writing. Furthermore, cordial thanks are extended to Science& Technology department of Chongqing for offer of fund.

References

[1] L.Hong,Y, Wan,and A.K.Jain, "Fingerprint Image Enhancement: Algorithm and Performance Evaluation," IEEE Transaction on Pattern Analysis and Machine Intelligence, vol. 20, no.8,,August 2001.

[2] L.L.Shen, A. Kol, and W.M Koo, "Quality Measures of Fingerprint Images," *3rd International Conference AVBPA 2001*, pp. 182-271, June 2001.

[3] E.Lim, X.D.liana. W.Y.Yau, "Fingerprint Quality and Validity Analysis," *IEEE Interdental Conference On Image Processing, IClP 2002,* September 2002. pp. 335-342.

[4] Ratha.NK, Bolle.R.M, "Fingerprint image quality estimation," IBM Computer Science, vol. LNCS2688, Guildford, UK, Springer 2003.

[5] B.M. Mehtre, "Fingerprint Image Analysis for Automatic Identification," Machine Vision and Applications, Springer-Verlag, vol. 6, pp.124-139, 1993.