Removal of periodic geometric structure in the fingerprint minutiae detection

Eduardo Castro[1]
eduardo.m.castro@inesctec.pt
Ana Rebelo[1]
arebelo@inesctec.pt
Carlos Gonçalves[2]
Carlos.Goncalves@incm.pt
Jaime S. Cardoso[1]
jaime.cardoso@inesctec.pt

[1] INESC TEC
Rua Dr. Roberto Frias
Porto, Portugal
[2] INCM
Edifício Casa da Moeda
Av. António José de Almeida
Lisboa, Portugal

Abstract

The main feature of the Portuguese Citizen Card is to allow the civil identification, in person or at a distance using electronic devices. The biometric identification is done through fingerprint images using specific points, called minutiae, for the matching. In this paper, a method to remove periodic geometric structure in the detected minutiae is proposed. The aim is to improve the interoperability according to the Minutiae Interoperability Exchange (MINEX) III program.

1 Introduction

An increasing number of biometrics have been deployed in real-world applications and its use is becoming a daily life practice for an ever growing number of people around the world. In consequence, a high level of reliability and robustness is required for sensitive applications such as border control, access control to military or laboratory facilities, as well as access to personal accounts for mobile on-line banking. Biometric traits can provide this automatic recognition measuring unique physical or behavioral characteristics.

Notwithstanding face has been preferred in a number of biometric applications (such as border control e-gates, on-line banking apps, CCTV surveillance identification, selfie-based authentication on smartphones, among others), fingerprint is still one of the most used biometric traits principally because of its social acceptance and stability.

Portugal was the pioneer with the "Match-on-Card" (MoC) fingerprint matching algorithm implemented in the national eID card. This technique brought very significant changes in this state: 1) modernization, 2) simplification and 3) technical evolution. The Portuguese National Printing Office – INCM (Imprensa Nacional Casa da Moeda SA), responsible for the creation of the method, provided to the Portuguese Government an innovative way of fingerprint matching in the card microprocessor without any contact to a central biometric database. The biometric information and the technology inserted in the Citizen Card allows an high security authentication. In this context, a national fingerprint recognition algorithm, hereafter referred to as fingerIDAlg, capable of MoC was developed by a Portuguese R&D institute in partnership with INCM. The main contributions of this work were: 1) an algorithm with higher accuracy than the previous solution; 2) an extremely competitive time processing MoC algorithm; and 3) an independent proprietary sensor solution [6].

Nevertheless, the proposed solution could still be improved in terms of minutiae geometric structure in order to be in compliance with NIST's Minutiae Interoperability Exchange (MINEX) III criteria guidelines[1]. In this work, a simple but effective solution is presented. The obtained results using the minutiae density plots and from the NIST's report proves exactly that. For architecture details of the fingerprint minutiae extraction algorithm the reader should consult the following paper [6].

2 Minutia Density Plots

Minutia density plots show where the template generator tends to find minutia in fingerprint images. They are 2D histograms where the degree of illumination at an (x, y) coordinate indicates how frequently the software located a minutiae point at that location – see Figure 1. The purpose of showing minutia density plots is to determine whether the template generator exhibits regional preference when locating minutia. Periodic structures and other regional preferences affects interoperability [7].

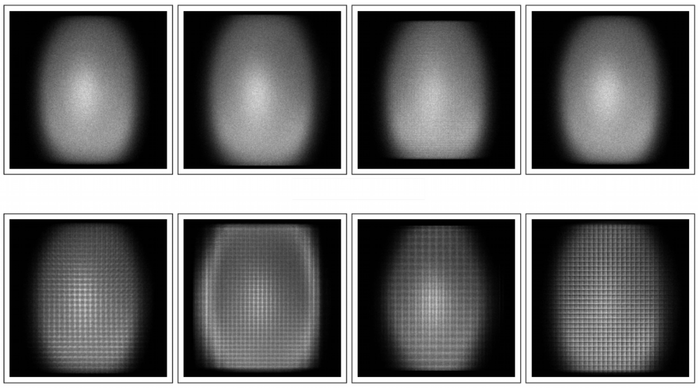


Figure 1: Comparison between natural (top) and unnatural (bottom) structures in the minutiae position.

The criterion regarding the obligation that the algorithm does not exhibit periodic behavior with respect to extracting the minutiae position is evaluated in a quantitative way, through a routine that is published [2], in a set of about 600k fingerprint images. The periodicity is measured as the highest coefficient of the Fourier representation of the minutiae position histogram, after removing some low frequency components. The measured value must be less than to a experimental value. A 0.002 was selected empirically by NIST.

3 Baseline

The positioning of minutiae extracted by fingerIDAlg has a periodic pattern in a fixed size grid – see Figure 2.

The reasoning of this periodic structure is in the way how the fingerIDAlg computes the orientation for each pixel in the image. In this module, an angle is calculated in an window of K pixels and the remaining pixels are obtained by interpolation. In this way the processing time is very significantly reduced and the use of local orientations allows less noise in the angles of the detected minutiae which an important factor in the matching process.

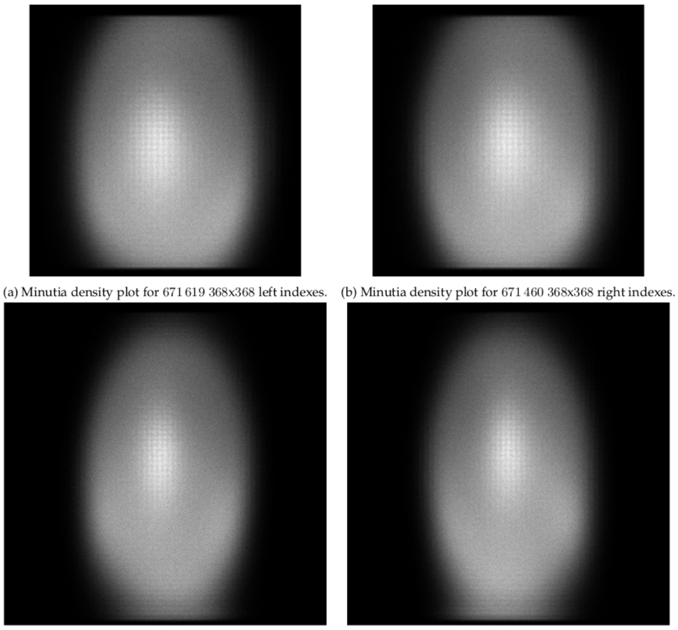
4 The Proposed Solution

The structure presented by fingerIDAlg in the extraction of minutiae corresponds to a periodic pattern in a fixed size grid determined by parameter K. In this manner, initially the image is moved X pixels to the right and Y pixels down. X and Y are determined in a pseudo-random manner in order to guarantee: 1) for the same input the same values are used; 2) the values vary between 0 and K-1 and 3) the possible values have the same probability of being obtained. The image is then processed by fingerIDAlg to extract the minutiae – see Figure 3. At the end, the position of each extracted minutia is corrected, moving again X pixels to the left and Y pixels upwards.

The proposed approach intends to *dilute* the grid previously presented in the histogram. Points with a high probability of generating minutiae

[1] https://www.nist.gov/itl/iad/image-group/minex-iii-compliance-guidelinesvisitadadia1/02/2020.

[2] https://github.com/usnistgov/minex/tree/master/minexiii/grid_detector



(a) Minutia density plot for 671 619 368x368 left indexes. (b) Minutia density plot for 671 460 368x368 right indexes.
(c) Minutia density plot for 477 312 500x500 left indexes. (d) Minutia density plot for 477 317 500x500 right indexes.

Figure 2: The obtained results of fingerIDAlg in the NIST's MINEX III.

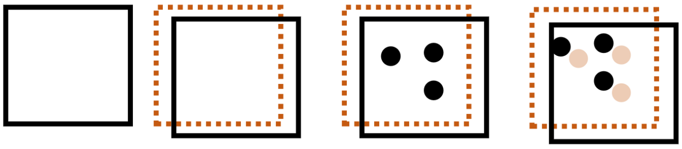


Figure 3: The proposed methodology to remove the periodic structure from the minutiae extraction phase.

will be distributed across the pixels in a $K \times K$ size square. Given its computational simplicity and the fact that it is a pre-and-pro-processing methodology the influence in the final accuracy and processing time is small.

5 Experimental Evaluation

5.1 Datasets

The Synthetic FINgerprint GEnerator (SFinGe) [5] was used to test offline the proposed methodology. In total, 800k images with a dimension of 260×264 and a resolution of 500 dpi were generated in SFinGe. Fingerprint images with background noise, pores, scars and cuts were generated. Different orientations were also included. Experiments were also conducted using the FVC databases: FVC2000 [3], FVC2002 [4], FVC2004 [1] and FVC2006 [2]. Each FVC database is composed of 4 subsets (DB1 A, DB2 A, DB3 A and DB4 A). The first 3 sets have a total of 800 images, acquired from 100 fingers with 8 samples per finger. FVC2006 comprises 1680 fingerprints images acquired from 140 fingers with 12 samples per finger. In total, 12240 fingerprints are available for testing the algorithms. The images have a resolution ranging from 250 to 569 dpi. The dimensions vary from 96 to 640 pixels in width, and 96 to 480 pixels in height.

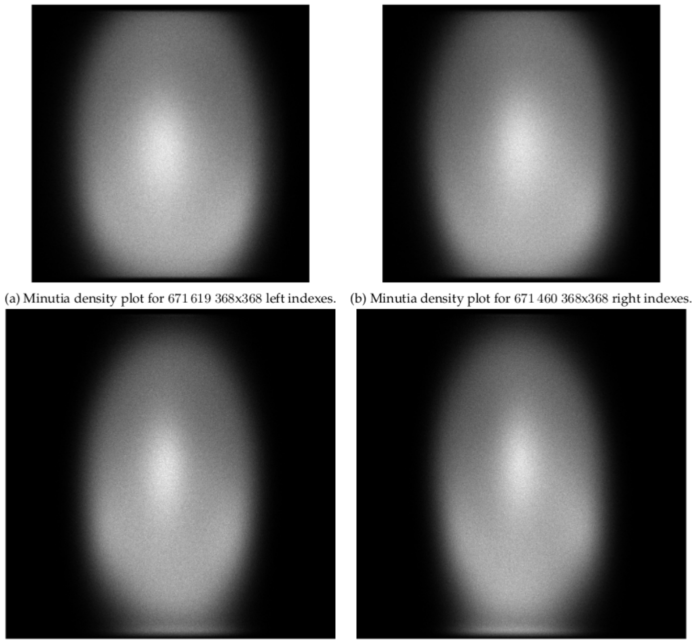
5.2 Results

The results are expressed in terms of Equal-Error Rate (EER) and the periodicity value (Z) computed from the minutiae density plots. The EER at the threshold t is obtained when both False Match Rate and False Non-Match Rate are identical: FMR(t)= FNMR(t). This score was computed, using the FVC Fingerprint Verification Protocol[3] and the matching algorithm from the INCM. Since the Z value is only possible to obtain with a significant amount of data, SFinge were used. In Figure 4 the results obtained in the NIST's MINEX III report are presented. The complete evaluation can be extracted from the MINEX III results page.

[3] https://biolab.csr.unibo.it/FVCOnGoing/UI/Form/BenchmarkAreas/BenchmarkAreaFV.aspx

Dataset	Average EER (baseline)	Average EER (periodicity removal)
FVC	2.528	2.608
800k	1.807	1.926
	Z (baseline)	Z (periodicity removal)
800k	0.0020	0.0010

Table 1: The obtained results before and after the proposed removal periodicity algorithm.



(a) Minutia density plot for 671 619 368x368 left indexes. (b) Minutia density plot for 671 460 368x368 right indexes.
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Figure 4: The obtained results of fingerIDAlg after removing the periodicity in the minutiae structure in the NIST's MINEX III.

6 Conclusion

The step for removing periodicity from the detection minutiae phase represents a trade-off between precision and periodicity without influencing the processing time. The experimental testing conducted – see Table 1 and the results in NIST's MINEX III report – see Figure 4 – reveal a significant reduction in the Z value without compromise the accuracy and the performance.

7 Acknowledgements

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