Fingerprint Image Compression Interoperability Analysis

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Abstract

In this project, we investigate the degree of interoperability among various fingerprint-matching algorithms using compressed enrollment (template) images compatible with ISO/IEC FCD 19794-3 [1]. The interoperability testing consists of three different fingerprint-matching algorithms: a pattern-based matching algorithm from Bioscrypt, and two minutiae-based matching algorithms from Innovatrics and Neurotechnologija. The 19794-3 compatible enrollment images are compressed with different parameter settings to assess the effect of these parameters.

1. Fingerprint database

A database of images from a Crossmatch V300 sensor, collected during Q1 and Q2 of 2004 is used for all interoperability testing. The size of each image is 640×480 (width $\times$ height) pixels. The resolution of each image is 500 dpi (dots per inch). The database consists of 150 fingers (LR, LM, LI, RI, RM, RR from each of 25 people). Each finger has 1 enrollment print and 10 verification prints.

2. Compression of enrollment images

The enrollment images are compressed using the pre-defined spectral-triple representation described in ISO/IEC FCD 19794-3. Below, we present a list of the particulars in our implementation.

- ISO/IEC FCD 19794-3 section 5.2 particular: The image is downsampled from 500dpi to 200dpi using bilinear downsampling, and image cropping is not performed. Note that image cropping would reduce the data storage requirements and minimize the extraneous artifacts seen in the outer portions of figure 2(b).
- ISO/IEC FCD 19794-3 section 5.3 particular: The image is partitioned into non-overlapping cells.
- ISO/IEC FCD 19794-3 section 5.4 particular: The distance measure used to select the best fitting spectral-triple parameters is L1 norm (absolute distance).

3. Testing Procedures

The testing procedures are summarized below:

- Preprocess each enrollment image with an open source fingerprint image enhancement algorithm [2], [3] for ridge enhancement (an example is shown in figure 1)
- Compress the enrollment image using the procedures described in section 2
- Store the compressed image
- Reconstruct the enrollment image from its spectral-triple representation, and upsample the reconstructed image from 200dpi to 500dpi using bilinear interpolation (an example is shown in figure 2)
- Match the reconstructed enrollment image against a verification print or an attacker print using each matching algorithm

Attacker prints are considered to be the first print in the verification set for every finger other than the finger from which the current template is derived. This means that there are 149 attacker prints for every template. Since there are 10 verification prints per finger, each enrollment print set contains 1500 (150×10) legitimate matching scores and 22350 (150×149) attacker matching scores.

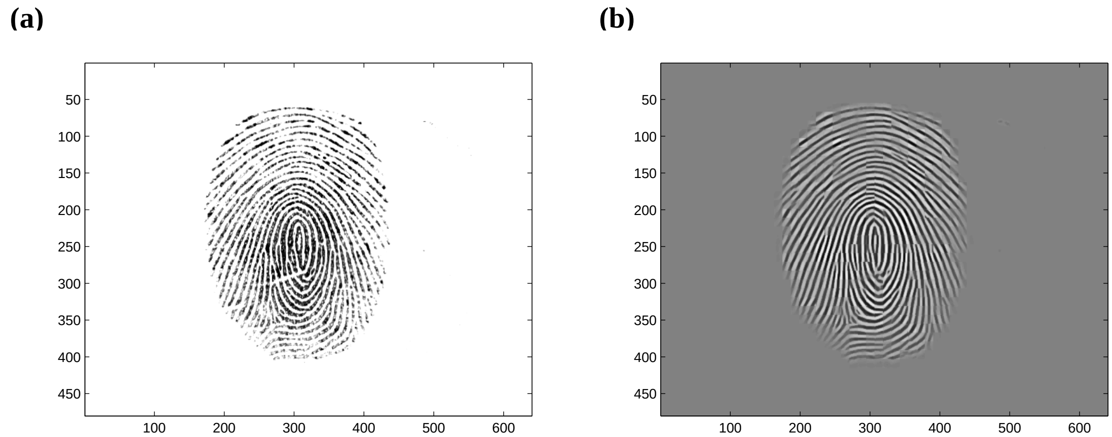

Fig. 1. An example of image preprocessing: (a) the original enrollment image, (b) the preprocessed enrollment image as a result of implementing the step in section 3, bullet 1.

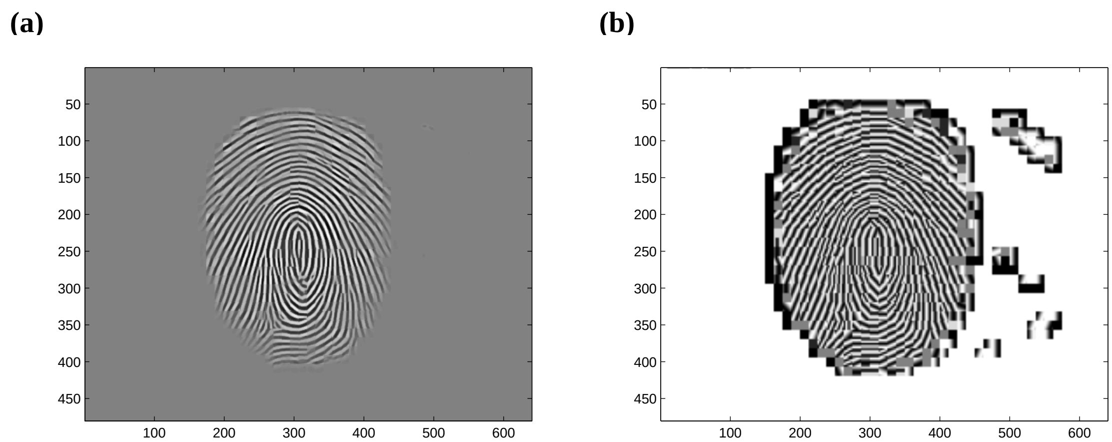

Fig. 2. An example of image reconstruction: (a) the preprocessed image from figure 1, (b) the reconstructed image as a result of implementing the step in section 3, bullet 4.

4. Results and Discussion

In the spectral-triple representation, each image is partitioned into finger pattern cells of size $s \times t$ pixels. The grey scale information in each finger pattern cell is approximated with a 2D cosinusoidal function defined by three parameters: propagation angle (θ), wavelength (λ), and phase offset (δ). The value of each of the three parameters can be quantized to create a limited set of discrete triples. For each finger pattern cell, the spectral-triple that yields the closest match is selected to represent this cell. In this section, we evaluate the performance of each matching algorithm using reconstructed enrollment images with different parameter settings. The performance is evaluated using ROC (Receiver Operating Characteristic) curves, EER (Equal Error Rate), and FRRs (False Rejection Rate) at selected FARs (False Acceptance Rate).

4.1. Performance comparison of different bit-depths

First, we vary the bit-depths of the spectral-triple parameters $\{\theta, \lambda, \delta\}$ using cell size of 5×5. The bit-depth is varied from 2 bits to 5 bits. For simplicity, we assume that these three parameters have the same bit-depth. Figure 3 shows the ROC curves obtained from the three matching algorithms. This figure shows that there is little difference in the ROC curves for bit-depths of 5 bits, 4 bits, and 3 bits. However, when the bit-depth is reduced from 3 bits to 2 bits, there is a significant change in ROC curves. This is true for all three matching algorithms. Tables 1, 2, and 3 show the corresponding EERs and FRRs at selected FARs for each matching algorithm. The results in these tables show that only when the bit-depth is reduced to 2 bits, there is a significant increase in EERs and FRRs. To reduce the amount of memory required to store the compressed images, a small bit-depth value is preferred. Therefore, a bit-depth of 3 bits should be selected for cell size of 5×5 pixels.

TABLE 1
COMPARISON OF EER AND FRRS AT DIFFERENT BIT-DEPTHS FOR CELL SIZE OF 5×5 PIXELS (BIOSCRYPT).

	{5,5,5}	{4,4,4}	{3,3,3}	{2,2,2}
EER	0.011	0.011	0.011	0.045
FRR at FAR=0.1	0.0047	0.0027	0.0033	0.027
FRR at FAR=0.01	0.012	0.011	0.011	0.095
FRR at FAR=0.001	0.025	0.024	0.024	0.19

TABLE 2
COMPARISON OF EER AND FRRS AT DIFFERENT BIT-DEPTHS FOR CELL SIZE OF 5×5 PIXELS (INNOVATRICS).

	{5,5,5}	{4,4,4}	{3,3,3}	{2,2,2}
EER	0.016	0.013	0.012	0.063
FRR at FAR=0.1	0.0093	0.0087	0.0087	0.049
FRR at FAR=0.01	0.016	0.015	0.012	0.11
FRR at FAR=0.001	0.025	0.021	0.021	0.18

TABLE 3
COMPARISON OF EER AND FRRS AT DIFFERENT BIT-DEPTHS FOR CELL SIZE OF 5×5 PIXELS (NEUROTECHNOLOGIJA).

	{5,5,5}	{4,4,4}	{3,3,3}	{2,2,2}
EER	0.024	0.024	0.023	0.10
FRR at FAR=0.1	0.0073	0.013	0.012	0.12
FRR at FAR=0.01	0.031	0.037	0.029	0.29
FRR at FAR=0.001	0.062	0.064	0.064	0.48

4.2. Performance comparison of different cell sizes

Next, we evaluate the performance of each matching algorithm by varying the cell size while keeping the bit-depth of each spectral-triple parameter to 5 bits. Although in Section 4.1 we concluded that parameter bit-depths of $\{3,3,3\}$ are optimal, this is specific to a cell size of 5×5 pixels. In order to test the effects on performance of varying cell sizes, we oversample the parameter bit-depths to $\{5,5,5\}$ to eliminate any bit-depth effects. The cell size is varied from 3 pixels to 7 pixels, square. To reduce the amount of memory required to store the compressed image, a larger cell size is desired. Figure 4 shows the ROC curves obtained from the three matching algorithms. From this figure, we can see that the performance does not change much when the cell size is varied from 3×3 pixels to 6×6 pixels. Only when the cell size is increased to 7×7 pixels do we begin to see a drop in performance. The results in tables 4, 5, and 6 further verify our observation. A cell size of 5×5 pixels thus represents a good compromise between performance and keeping the cell size large for minimal storage requirements.

5. CONCLUSIONS

In this project, we have quantitatively evaluated the degree of interoperability among various fingerprint-matching algorithms using compressed enrollment images compatible with ISO/IEC FCD 19794-3. The 19794-3 compatible enrollment images have been compressed with different parameter settings to analyze the effect of these parameters. Future work may include varying the bit-depths independently as well as a further study on non-square and overlapping cell sizes.

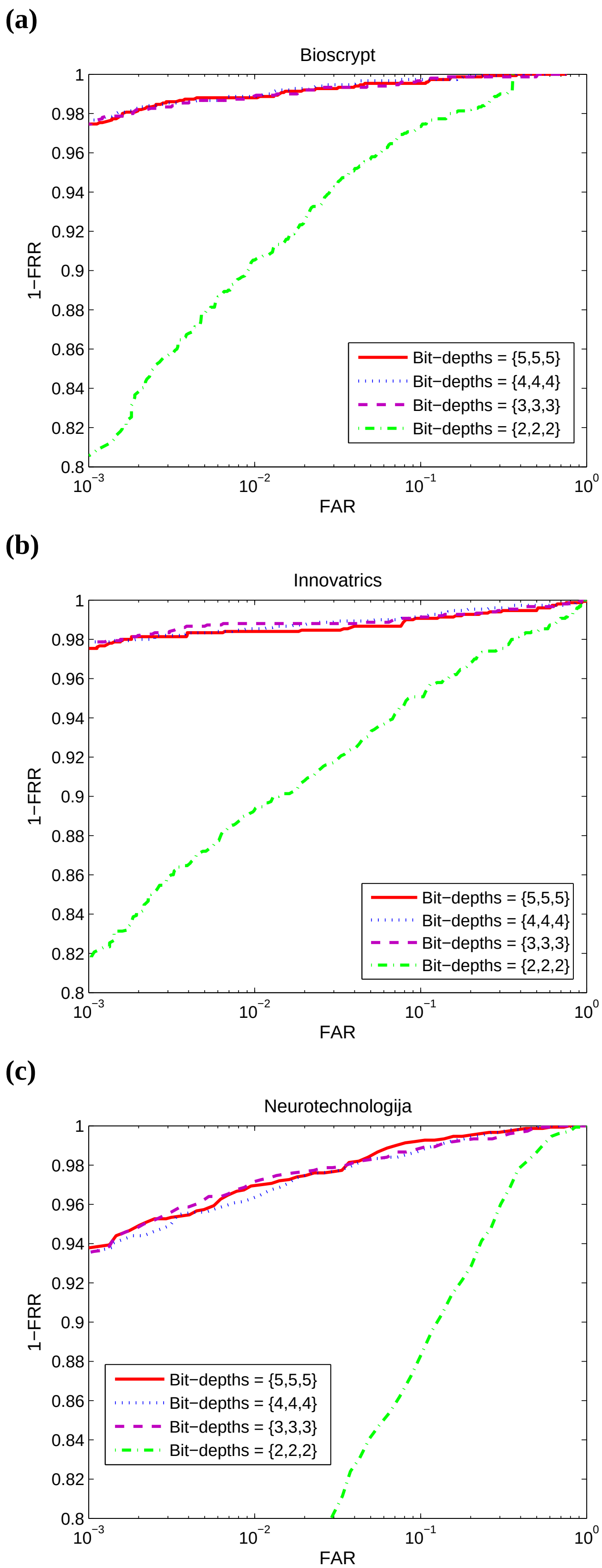

Fig. 3. ROC curve comparison of different bit-depths for cell size of 5×5: (a) Bioscrypt, (b) Innovatrics, and (c) Neurotechnologija.

REFERENCES

[1] ISO/IEC FCD 19794-3, Biometric Data Interchange Formats – Part 3: Finger Pattern Spectral Data, Dec. 23, 2004.
[2] S. Chikkerur, "Fingerprint image enhancement algorithm," http://www.eng.buffalo.edu/∼ssc5/.
[3] S. Chikkerur, C.Wu, and V. Govindaraju, "A systematic approach for feature extraction in Fingerprint Images," ICBA 2004.

TABLE 4

COMPARISON OF EER AND FRRS AT DIFFERENT CELL SIZES FOR BIT-DEPTHS OF {5,5,5} (BIOSCRYPT).

	3×3	4×4	5×5	6×6	7×7
EER	0.0080	0.0080	0.011	0.012	0.016
FRR at FAR=0.1	0.0013	0.0020	0.0047	0.0040	0.0080
FRR at FAR=0.01	0.0060	0.0080	0.012	0.013	0.023
FRR at FAR=0.001	0.019	0.017	0.025	0.027	0.038

TABLE 5

COMPARISON OF EER AND FRRS AT DIFFERENT CELL SIZES FOR BIT-DEPTHS OF {5,5,5} (INNOVATRICS).

	3×3	4×4	5×5	6×6	7×7
EER	0.013	0.013	0.016	0.015	0.015
FRR at FAR=0.1	0.0093	0.0087	0.0093	0.012	0.0093
FRR at FAR=0.01	0.014	0.013	0.016	0.016	0.018
FRR at FAR=0.001	0.021	0.023	0.025	0.022	0.032

TABLE 6

COMPARISON OF EER AND FRRS AT DIFFERENT CELL SIZES FOR BIT-DEPTHS OF {5,5,5} (NEUROTECHNOLOGIJA).

	3×3	4×4	5×5	6×6	7×7
EER	0.021	0.023	0.024	0.023	0.023
FRR at FAR=0.1	0.011	0.015	0.0073	0.012	0.0087
FRR at FAR=0.01	0.027	0.031	0.031	0.029	0.036
FRR at FAR=0.001	0.063	0.054	0.062	0.065	0.086

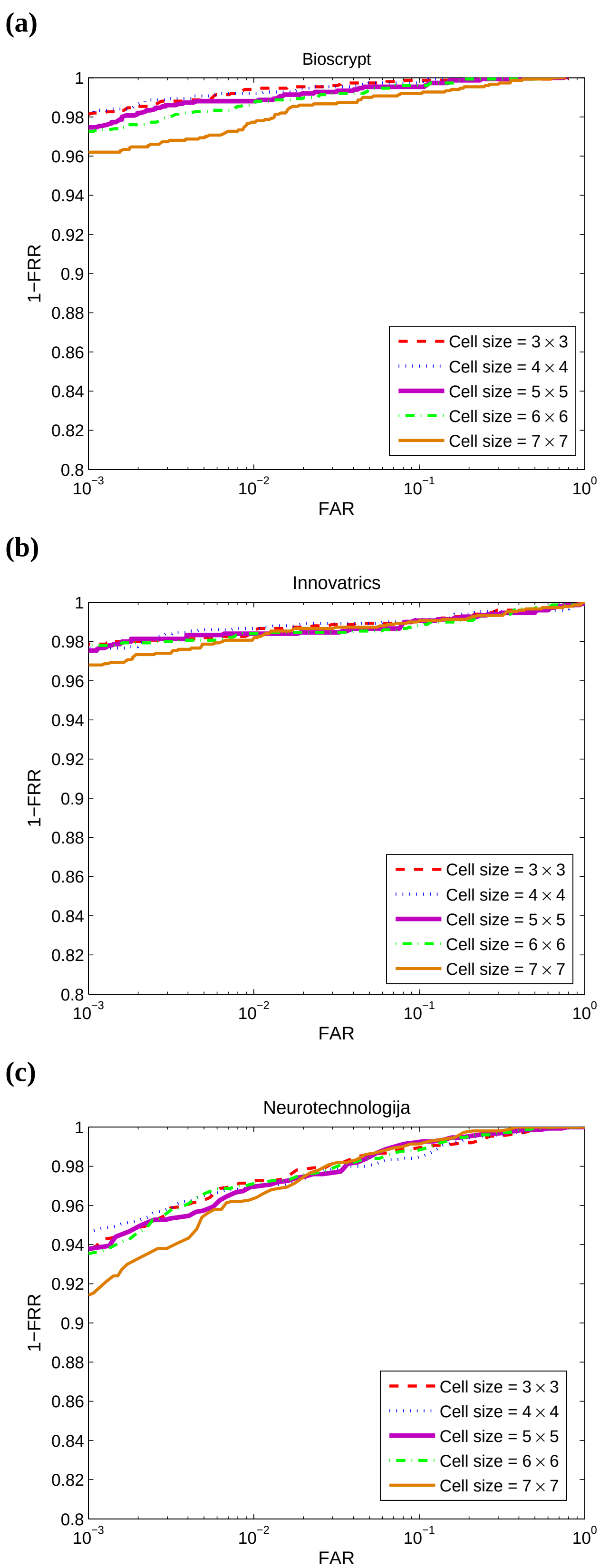

Fig. 4. ROC curve comparison of different cell sizes for bit-depths of {5,5,5}: (a) Bioscrypt, (b) Innovatrics, and (c) Neurotechnologija.