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FINGERPRINT VERIFICATION SYSTEM USING PRINCIPAL COMPONENT TRANSFORMATION EIGENVECTORS TECHNIQUE

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Abstract

A fingerprint verification technique is presented. The Principal Component Transformation "PCT" is used to identify a checked person, by comparing its eigenvector with the PCT eigenvectors of stored fingerprints images in a Database. The computed Eigenvectors of the input images are determined from the covariance matrix of the set of fingerprints reduced mean images which were ascended as column vectors in a two dimensional array. The covariance matrix then determined by multiplying the mean (i.e. average) reduced matrix by its transpose. The similarity between the stored images of the fingers (as Database) and the test finger is presented by utilizing the Minimum Mean Square Error (MMSE) criterion.

نظام تحقق لطبعات الأصابع باستخدام تقنية المتجهات الذاتية لتحويلة المركبات الأساسية

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الخلاصه

تم في هذا البحث استحداث تقنية لتميز طبعات الأصابع والتحقق منها. استخدمت التقنية تحويلة المركبات الأساسية للتحقق من الشخص تحت الاختبار، وذلك بمقارنة متجهه الذاتي مع المتجهات الذاتية المخزنة في قاعدة البيانات. تم حساب المتجهات الذاتية لصور الطبعات من مصفوفة التغاير لصور الطبعات المطروح منها الصورة الممثلة لمعدل جميع الصور تحت الاختبار. مصفوفة التغاير، عادة، يتم حسابها من حاصل ضرب مصفوفة الصور مطروح منها الصورة المعدل بالمصفوفة التي تمثل محولتها. درجة التشابه بين المصفوفات الذاتية تم حسابها باستخدام معيار معدل-مربع-الخطأ-الأصغر.

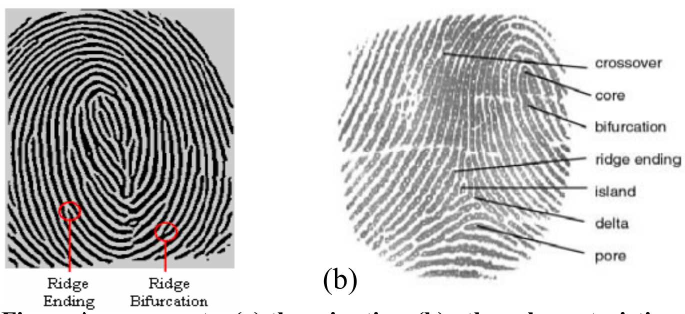
Introduction

Person detection is a challenging problem in computer vision for human computer interaction. Fingerprint recognition or fingerprint authentication was one of the most well known automated methods for verifying a matching between human fingerprints. It is, thus, one of many forms of biometrics used to identify an individual and verify their identity. Biometric systems are mainly designed to detain the statistics of image samples (e.g. fingerprints, eye-irises, human-faces, etc). The analysis of fingerprints for matching purposes generally requires the comparison of several features of the print pattern. These include ***patterns*** (represented by and aggregate characteristics of ridges), and ***minutia*** points (are unique features found within the patterns), [١]. Generally, fingerprint core is used to represent the reference point for the fingerprint features that take in consideration for most image recognition techniques. This core point represents the center of the innermost curve within the fingerprint. In fact, fingerprints usually appear as a series of dark lines that represent the ***peak points*** of the friction of ridge skin (***called minutiae***), while the ***valleys*** between these ridges appears as white spaces, as illustrated in figure (١), [٢]. Fingerprint identification, thus, based primarily on locations, directions, endings, and bifurcations of these minutiae.

However, some mathematical image transformation is, usually, used to build the biometric features that have less dimensionality than the original data. In this research, the PCT has been adopted to statistically analyzing the images of fingers data [٣]. The PCT's eigenvectors are used to perform the verification process between the persons fingerprint's images. The eigenvectors describe the contribution of each finger print eigenimages in representing the input image. These vectors can be used to determine the class of the input image by calculating the minimum distance from a projection vector in the training set. The distance between two vectors reflects the similarity between them. Hence two vectors with shortest distance refer to the most similar vectors [٣].

Normally, there are three basic patterns of fingerprint ridges; i.e. ***arch, loop, and whorl,*** as illustrated in figure (٢), [٤]. An arch is a pattern where the ridges enter from one side of the finger, rise in the center forming an arc, and then exit the other side of the finger. The loop is a pattern where the ridges enter from one side of a finger, form a curve, and tend to exit from the same side they enter. In the whorl pattern, ridges form circularly around a central point on the finger. One of the most common problems in delineating the ridges, using certain edge detection method, is the inking patches usually appears with the prints of the finger images (see figure ٣).

(a)



(b)

Figure ١: represents; (a) the minutiae, (b) other characteristics. [٤]

(a) arch pattern *(b) loop pattern* *(c) whorl pattern*

Figure ٢: represents the most common types of fingerprints ridges patterns, [٤].

(a) (b) (c) (d)

Figure ٣: Samples of fingerprint images, showing the inking effects.

Image Pre-Processing Operations

To overcome the problem of the inking problem, we shall perform the following operations:

٢.١ Image Feature Enhancement Method:

To reduce the inking effect and visualize the fingerprint features (i.e. Peaks and Valleys lines), we introduced the following image enhancement-normalization method. Let a fingerprint image function *f(x, y) of m×n* pixels size, its mean and standard deviation are given by;

$$\hat{f} \approx \frac{1}{m \times n} \sum_{x=1}^{m} \sum_{y=1}^{n} f(x,y) \qquad (١)$$

$$\sigma = \sqrt{\frac{1}{m \times n} \sum_{x=1}^{m} \sum_{y=1}^{n} (f(x,y) - \hat{f})} \qquad (٢)$$

Image normalization (or binarization) is then performed by;

$$f_n(x,y) = \begin{cases} \hat{f} + \sigma & if \;\; f(x,y) \geq \hat{f} \\ \hat{f} - \sigma & if \;\; f(x,y) < \hat{f} \end{cases}$$

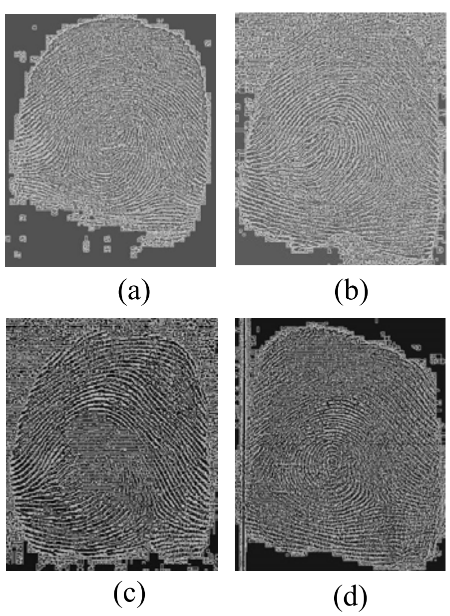


Figure ٤: Normalized fingerprint images.

Figure (٤), illustrates the normalized images of the fingerprint samples shown in figure (٣).

Extracting a Predefined Size of Fingerprint image Surrounding the Core Point

Mostly, the crucial features of fingerprints are surrounded the finger's core point. In this paper, the features surrounded the core points of the images (shown in figure (٤)), have been extracted in arrays of sizes ١٢٨×١٢٨ pixels, as illustrated in figure (٥). The extracted images will be used to identify an unknown print of fingers by comparing its features with the features of images that preserved in the database, for the details of defining the finger core see [١].

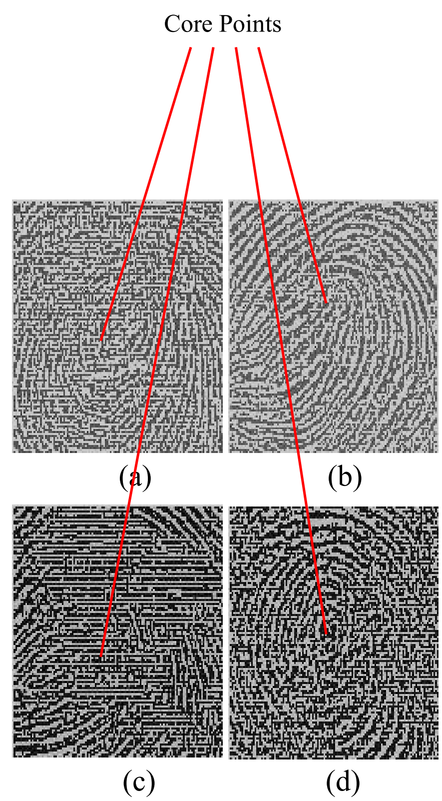


Figure ٥: Sub-images form of finger images, each has a size ١٢٨×١٢٨ pixels, surrounding the core points.

The PCA Eigenvectors

The PCA is a feature space transformation designed to remove the redundancies existed between similar functions (i.e. images). This transformation, also, known as the Karhunen-Loeve (KL) or Hotelling Transformation, it is a linear transform [٥]:

$$PC = W_{PC} . Y \qquad (٤)$$

Where; *PC* is the output principal component vector, *Y* is the image spectral vector, and W_{PC} is a weight matrix.
This transformation alters the covariance matrix *C* as follows;

$$C_{PC} = W_{PC} C W_{PC}^{T} = \begin{bmatrix} \lambda_1 & . & . & . & 0 \\ . & \lambda_{21} & . & . & . \\ . & . & \lambda_3 & . & . \\ . & . & . & . & . \\ 0 & . & . & . & \lambda_K \end{bmatrix} \qquad (٥)$$

The *K* eigenvalues λ_K are found as the roots of the following characteristic equation, [٥];

$$| C - \lambda I | = 0 \qquad (٦)$$

Where: *C* is the covariance matrix of original data, and *I* is the diagonal identity matrix.

The *PC* coordinate axes are defined by the *K* eigenvectors while e_K, obtained from the following vector-matrix equation, for each eigenvalue λ_K;i.e.

$$| C - \lambda I | e_K = 0 \qquad (٧)$$

which form the rows of the following transformation matrix W_{PC};

$$W_{PC} = \begin{bmatrix} e_1^T \\ . \\ . \\ e_K^T \end{bmatrix} = \begin{bmatrix} e_{11} & . & . & e_{1K} \\ . & & & . \\ . & & & . \\ e_{K1} & . & . & e_{KK} \end{bmatrix} \qquad (٨)$$

Where: e_{ij} is the j^{th} element of the i^{th} eigenvector.

Computation of the Fingerprints Eigenvectors:

In our present research, the normalized-extracted fingerprint images, each of size ١٢٨×١٢٨ pixels, are firstly arranged in an array, as column vectors, as shown in the matrix form following.

$$\begin{bmatrix} image_1 & image_2 & image_3 & \dots & image_M & image_{M+1} \\ \Gamma_{1,1} & \Gamma_{1,2} & \Gamma_{1,3} & \dots & \Gamma_{1,M} & \Gamma_{1,M+1} \\ \Gamma_{2,1} & \Gamma_{2,2} & \Gamma_{2,3} & \dots & \Gamma_{2,M} & \Gamma_{2,M+1} \\ \Gamma_{3,1} & \Gamma_{3,2} & \Gamma_{3,3} & \dots & \Gamma_{3,M} & \Gamma_{3,M+1} \\ . & . & . & \dots & . & . \\ . & . & . & \dots & . & . \\ \Gamma_{N,1} & \Gamma_{N,2} & \Gamma_{N,3} & \dots & \Gamma_{N,M} & \Gamma_{N,M+1} \end{bmatrix}$$

As it is obvious, the training set of the fingerprint images and the test image are presented, respectively, by $\Gamma_{i,(i=1,2,3...M)}$, and Γ_{M+1} . The average image of the fingers is, thus given by, [٦]:

$$\overline{\Gamma} = \frac{1}{M+1} \sum_{i=1}^{M+1} \Gamma_i \qquad (٩)$$

The average reduced images could be computed by subtracting the average fingerprint image elements from the corresponding training fingerprint elements; i.e.:

$$\Phi_i = \sum_{i=1}^{M+1} [\sum_{j=1}^{N} (\Gamma_{i,j} - \overline{\Gamma})] \qquad (١٠)$$

Where: Φ_i represent the i^{th} average reduced fingerprint image (referred as the ***Eigenfingerprint***). The ***covariance matrix*** *(of size (M+١)×(M+١) elements)* of these Eigenfingerprint could be computed as follows:

$$C = \Phi^T \Phi \qquad (١١)$$

Where: T represent the matrix transposition.
The eigenvectors could be computed from:

$$Ce_k = \lambda_k e_k, \qquad for\ k = 1,2,..,M+1 \qquad (١٢)$$

The final step in the recognition process is test the similarity between the verify fingerprint and the trained set, using the Minimum Mean Square Error "MMSE" test, given by [٦];

$$MMSE = Min\{\frac{1}{M} \sum_{i=1}^{M} (e_{K,i} - e_{M+1,i})^2\}, \quad for\ K = 1,2,..,M \qquad (١٣)$$

Experimental Results

The procedures involved in our designed fingerprint's verification system are illustrated in the block-diagram shown in figure (٦). Set of samples which have been extracted from the original images are shown in figure (٧). An extracted fingerprint (used to test) is shown in figure (٨), representing figure (٧b). The average image of the Database plus the test images is shown in figure (٩).

The average reduced fingerprint images are shown in figure (١٠).

Table-١- represents the Eigenvectors of the whole; i.e. Database and the test image. The last row of the table shows the counted MMSE between the last Eigenvector and the vectors belong to the Database images.

Table ١: The computed eigenvectors for the test image shown in figure ٩.

Eigenvectors	Image١	Image٢	Image٣	Image٤	Image٥	Image٦	Image٧	Image٨
e١	٠.٩١٢٦٥٣	٠.٣٨٩١٤٥	٠.١٢٠٤١٣	٠.٠٢٢٣٧٣	٠.٠٢١٨٠٤	-٠.٠١٠١٥	-٠.٠٠٧٢٣	٠.٠٠٠٠٠٠
e٢	٠.٠٢٠١٣١	-٠.٠١٦٣٩	-٠.٠١٢٦١	-٠.٦٧٨٧٠	٠.١٧٥١٥١	-٠.٠٢٧٥٥	-٠.٠٨٤٢٦	-٠.٧٠٧١١
e٣	٠.٠٦٠٤٣٦	-٠.٠٥٥١٨	-٠.٠٩٧٦١	-٠.٢١٦٥٠	-٠.٩٢٧٩٧	-٠.٢٦٩٢٦	-٠.٠٥٧٢٤	٠.٠٠٠٠٠٠
e٤	٠.٢٩٠١٣١	-٠.٤٢٧٨٨	-٠.٨٤٥٩٤	٠.٠٦٣٠٠٣	٠.١١٠٥٢٥	٠.٠٢٩٦٨٦	-٠.٠٠٨٣٤	٠.٠٠٠٠٠٠
e٥	٠.٢٧٨٢٣٤	-٠.٨١٣٢٢	٠.٥٠٩٦٠٩	٠.٠٢٣٨٤٢	٠.٠١٥٣٩٤	-٠.٠٢٧٢٩	-٠.٠٠٢٦٩	٠.٠٠٠٠٠٠
e٦	٠.٠٢٥٢٥٩	-٠.٠٢١٣٧	٠.٠١٤٦٩٧	-٠.٠٩٠٤٣	-٠.٢٤٩٧٤	٠.٩٥٨٥٨٤	-٠.٠٩٦٢٣	٠.٠٠٠٠٠٠
e٧	٠.٠١٩٣٠٧	-٠.٠١١٠٧	-٠.٠١١٢٦	-٠.١٣٦٥٧	-٠.٠٤٧١٥	٠.٠٧٣٢٧٧	٠.٩٨٦٤٧٦	٠.٠٠٠٠٠٠
e٨	٠.٠٢٠١٣١	-٠.٠١٦٣٩	-٠.٠١٢٦١	-٠.٦٧٨٧٠	٠.١٧٥١٥١	-٠.٠٢٧٥٥	-٠.٠٨٤٢٦١	٠.٧٠٧١١
MMSE is obvious between e ٢ & e٨, its = ٠, if < ٨ elements were adopted								

.

Conclusion

In this paper, a recognition system is designed to verify persons from their fingerprint images. The scheme is appropriate to be operated as an authentication system on offices security in which the fingerprint features of the employees can be preserved as a Database, and then open-door permission to peoples having record in Database, otherwise he is rejected. In fact, the PCA technique is implemented to differentiate between human facial images, see [٦], and proved to be invariant with little degree of scaling, rotation, and noise. It should be noted that, the presented system has been implemented on a set of ٢٥ finger print image. The result was the same as that acquired with the ٨-teste images. However, more work is still being required to test the sensitivity of the system for inking effect.

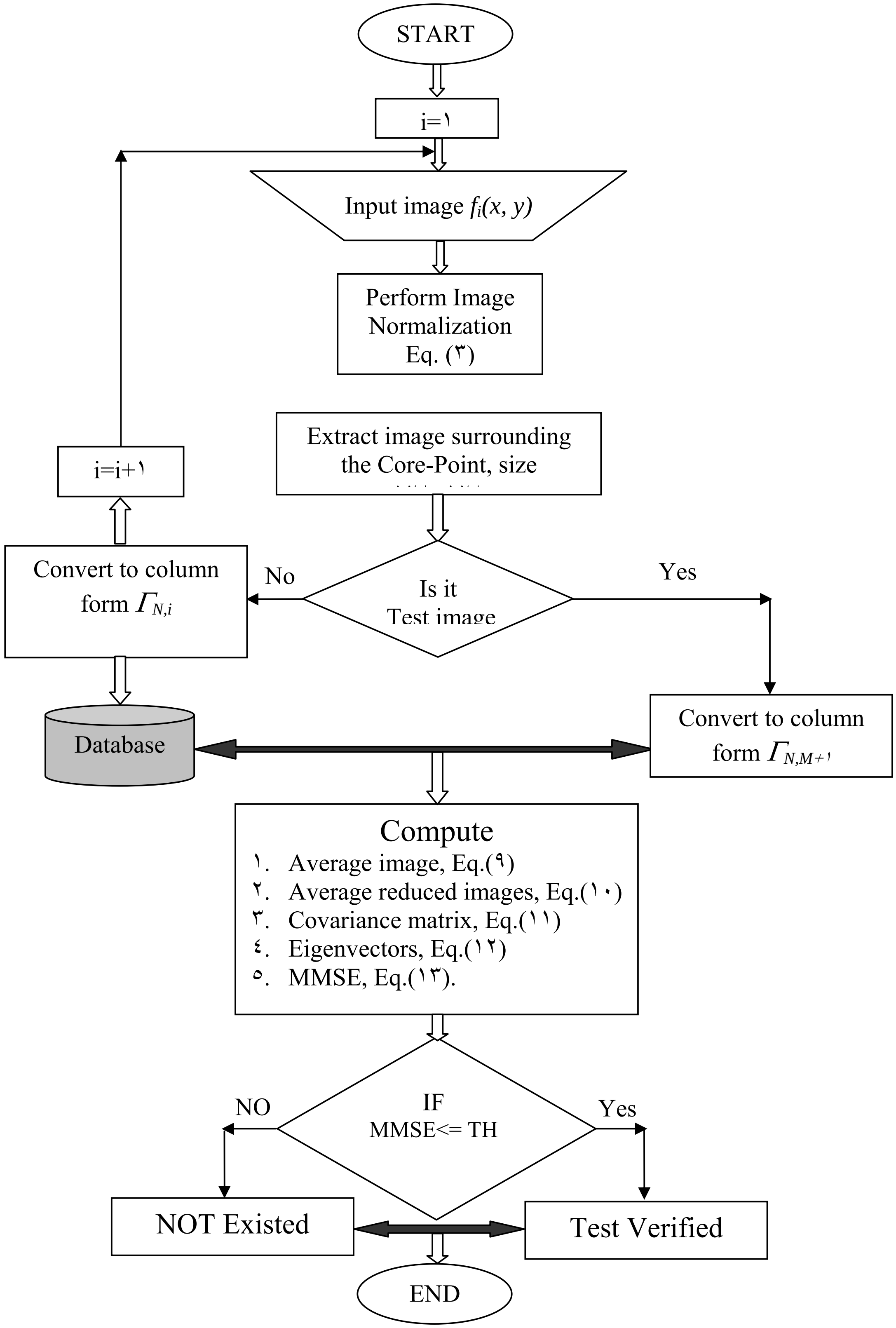


Figure ٦: A block-diagram summarizes the procedures involved in our designed verification system.

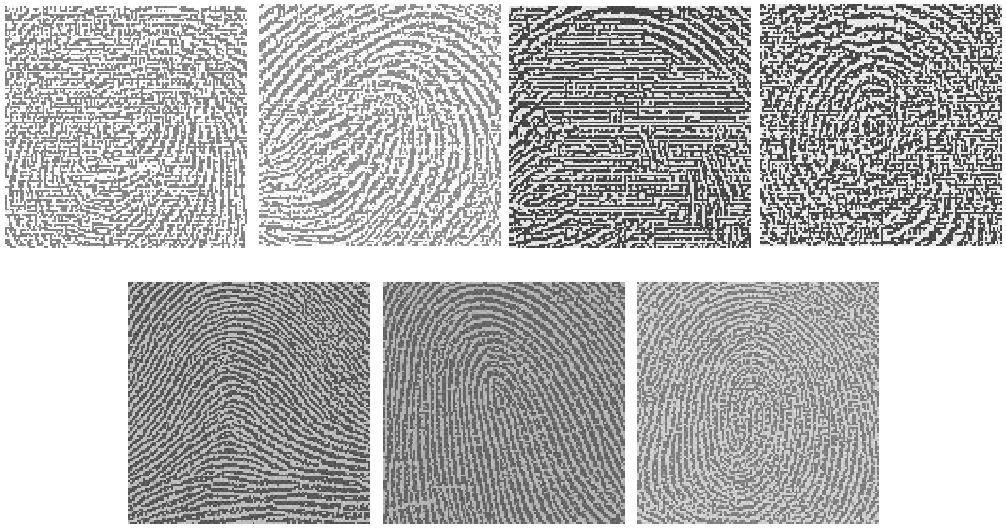


Figure ٧: A set of seven extracted fingerprint images, used as a database for the verification test.

Figure ٨: The test image, used for the verification test, represents the ٢nd image in figure.٧.

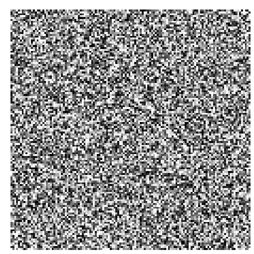


Figure ٩: The average image of the prints shown in figures ٧ and ٨.

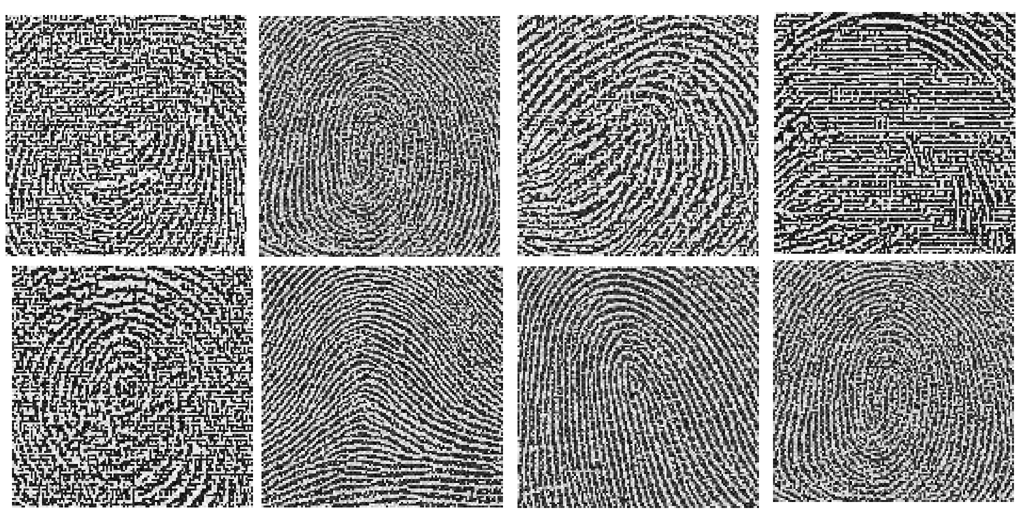


Figure ١٠: The average reduced images of the database prints (١→٧), and the test print image #٨.

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