Multimodal Biometric System Based on Fingerprint Identification and Iris Recognition

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Abstract—**Mono modal biometric systems encounter a variety of security problems and present sometimes unacceptable error rates. Some of these drawbacks can be overcome by setting up multimodal biometric systems. Multimodal biometrics consists in combining two or more biometric modalities in a single identification system to improve the recognition accuracy. However features of different biometrics have to be statistically independent. This paper proposes a multimodal biometric systems using fingerprint and iris recognition.**

Keywords-component; Multimodal Biometric; fingerprint identification; iris recognition; matching

I. Introduction to Biometry

Biometry is the science of recognizing a person based on a physiological or behavioral characteristic like as face, fingerprints, hand geometry, handwriting, iris, retinal, vein, and voice [1][2].

Biometric technologies are becoming the groundwork of a wide array of highly secure identification and personal verification solutions. As the level of security breaches and transaction fraud rise, the need for highly secure identification and personal verification technologies is becoming essential.

II. Monomodal Biometry

The mono modal biometric process starts from sensors generating measurement data. Then, features are extracted from, to serve as identity templates and a comparison step is usually used between the tested feature and those coming from a database to decide about the identity.

Frequently studied biometric modalities are divided into two sets: physiological and behavioral [3][4].

Physiological characteristics are permanent without disturbance to the individual such as fingerprint, hand geometry, palm print, iris pattern, retina pattern, facial feature.

Behavioral traits reproduce a person physiological state like human voice, dynamic signature analysis, keystroke dynamics,...

III. Needs for Multimodal Biometric Systems

It has lately been reported to the U.S. Congress that about 2% of the population lack a legible fingerprint and thus cannot be enrolled into a fingerprint biometrics system [5]. The report suggests a system employing dual biometrics in an encrusted approach for large-scale applications such as border crossing.

Use of multiple biometric indicators for recognizing persons, known as multimodal biometrics, has been shown to enhance precision and population coverage, while decreasing vulnerability to spoofing.

IV. Related Work

Numerous studies confirm the advantages of multimodal biometrics in the literature.

Hong and Jain [6] suggest an identification system based on face and fingerprint, where fingerprint matching is applied after pruning the database via face matching.

Brunelli and Falavigna [7] choose the fusion of voice and face recognition for a hierarchical scheme of multimodal identification system and use hyperbolic tangent (tanh) for normalization and weighted geometric average.

Ben-Yacoub et al. [8] consider the Bayes classifier for face and voice biometrics recognition.

V. Developed Approach

The developed approach is based on a fusion of fingerprint recognition and iris identification.

A. *Fingerprint Recognition*

Fingerprint recognition is the most consistent biometric modality in use, since digital fingerprints are more convenient and less disturbing than most of the other biometric methods and they are already accepted as an immutably single identifier [9][10].

A fingerprint is the feature pattern of one finger. It is composed of ridges and furrows that present good similarities in each small local window, like parallelism and average width.

However, revealed by rigorous research on fingerprint recognition, fingerprints are not distinguished by their ridges and furrows, but by Minutia, which are atypical points on the ridges [11].

There are several minutia types: termination (the immediate ending of a ridge), bifurcation (the point on the ridge from which two branches derive), island (a ridge that commences, travels a short distance and then ends), ridge enclosures (a single ridge that bifurcates and reunites shortly afterward to continue as a single ridge), spur (a bifurcation with a short ridge branching off a longer ridge), crossover or bridge (a short ridge that runs between two parallel ridges), …

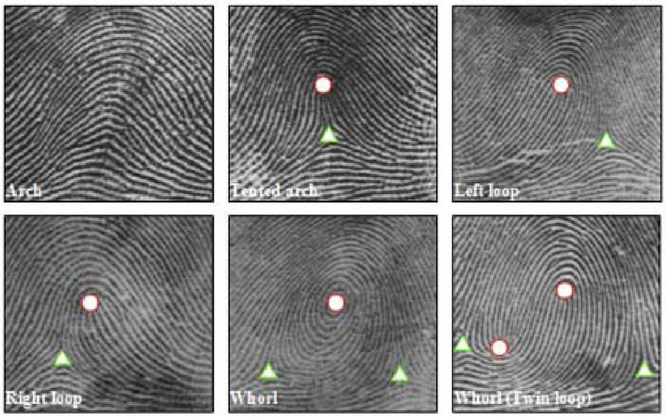

Figure 1. Examples of minutiae types

1) Fingerprint recognition:

The fingerprint recognition field can be grouped into two sub-domains: the verification step and the identification step.

The verification step consists in confirming the authenticity of one person by his fingerprint. The user provides his fingerprint together with his identity information and the system retrieves the fingerprint template according to the ID number and matches the template with the real-time acquired fingerprint from the user.

Fingerprint identification is to specify one person's identity by his fingerprint(s). Without knowledge of the person's identity, the fingerprint identification system attempts to match his fingerprint(s) with those in the fingerprint database. It is particularly useful for criminal investigation cases.

However, all fingerprint recognition problems, either verification or identification, are ultimately based on a well-defined representation of a fingerprint.

There are two representations forms for fingerprints related to the two approaches for fingerprint recognition: the minutia-based approach which represents the fingerprint by its local features (like terminations and bifurcations), and the image-based approach which aims to do matching based on the global features of a whole fingerprint image.

2) Fingerprint representation

In our work we have adopted the first approach based on minutiae extraction.

The first step consists in an image preprocessing. In fact, the fingerprint image is enhanced to make it clearer for easy further operations by increasing the contrast between ridges and furrows.

For this, we adopted an image normalization step using the arithmetic average M of the image gray levels and its variance V.

$$M(I) = \frac{1}{H * L} \sum_{i=1}^{H} \sum_{j=1}^{L} I(i,j) \tag{1}$$

$$V(I) = \frac{1}{H * L} \sum_{i=1}^{H} \sum_{j=1}^{L} (I(i,j) - M)^2 \tag{2}$$

The resulting matrix G after normalization step is:

$$G(x,y) \begin{cases} M_0 + \sqrt{\dfrac{V_0 (I(i,j) - M)^2}{V}} & \text{if I (i,j) <M} \\ M_0 - \sqrt{\dfrac{V_0 (I(i,j) - M)^2}{V}} & \text{if not} \end{cases}$$

where M0 and V0 represent respectively the ideal values of M and V

Figure 2. Normalization Process.
Original Image (Left). Normalized image (Right)

The next step consists in binarizing the fingerprint image by transforming the 8-bit Gray fingerprint image to a 1-bit image with 0-value for ridges and 1-value for furrows.

Figure 3. Binarization step.
Original Image (Left). binarizd image (Right)

Given that, only a Region of Interest (ROI) is useful to be recognized for each fingerprint image, we use morphological operators (open/close) to extract these ROI. After that, a block direction estimation and direction variety check is needed.

For this, we need to divide the image into 16x16 pixels, calculate the gradient values for each pixel using Sobel filter, and get the Least Square approximation of the block direction using the following equation:

$$tg2ß = 2 \Sigma \Sigma (g_x * g_y) / \Sigma \Sigma (g_x^2 - g_y^2) \quad (4)$$

The tangent value of the block direction is subsequently estimated as:

$$tg2\theta = 2\sin\theta \cos\theta / (\cos^2\theta - \sin^2\theta) \quad (5)$$

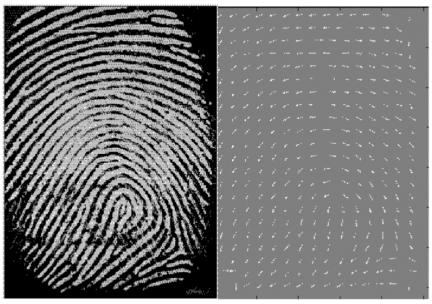

Figure 4. Direction map.
Binarized fingerprint (left), Direction map (right)

3) Minutia extraction

Minutia extraction is processed in 4 steps:

- Fingerprint ridge thinning by eliminating the redundant pixels of ridges till the ridges are just one pixel wide [12][13].
- Minutia marking
- False minutia removal
- Unification of terminations and bifurcations: Since various data acquisition conditions such as impression pressure can easily change a minutia form into a different one, we adopt the unification representation for both termination and bifurcation. So each minutia is wholly described by its coordinates (x,y) and its orientation.

Figure 5. Minutia Extraction.

4) Minutia match

The minutia match algorithm settles on whether two set of minutia of two fingerprint images belong to the same finger or not [14].

The first step consists in aligning the couple of fingerprint images to be matched.

Thus we choose a minutia from each image and calculate the similarity of the associated ridges. If the similarity is larger than a fixed threshold, we transform each set of minutia to a new coordination system whose origin is at the referenced point and whose x-axis is coincident with the direction of the referenced point.

In the matching step, we count the matched minutia pairs of two set of transformed minutia points and we assume identical, two minutia having nearly the same position and direction.

B. Iris recognition

The iris is the colored part of the eye behind the eyelids, and in front of the lens. The function of the iris is to control the amount of light entering through the pupil by the sphincter and the dilator muscles, which adjust the size of the pupil [15]. These visible patterns are unique to all persons and the chance to find two individuals with identical iris patterns is about zero.

For our developed approach of iris recognition, the input is an eye image, and the output is the iris template (a mathematical representation of the iris region) [16].

The algorithm consists in 3 steps: segmentation, Normalization and Feature encoding.

1) Segmentation

It consists in separating the iris region in two circles: the iris/sclera boundary and the iris/pupil one. This step is decisive to the success of an iris recognition system, since wrong iris pattern will alter the generated biometric templates, and cause poor recognition rates [17].

For this, we require good quality of the used images.

We have used images provided by CASIA (Institute of Automation, Chinese Academy of Sciences). The images were taken exclusively for the purpose of iris recognition software research and implementation. Infra-red light was used for illuminating the eye, and hence they do not involve any specular reflections. For this reason, we do not proceed for a reflection error's removal.

The segmentation step consists in applying Canny edge detection to generate an edge map, then using circular Hough transform to detect the iris and pupil boundaries and deduce their radius and centre coordinates [18] .

To increase the efficiency of the circle detection process, we apply the Hough transform for the iris/sclera boundary first, then for the iris/pupil within the iris region, instead of the whole eye region. As a result, six parameters are stored: the radius, and (x, y) centre coordinates for both circles.

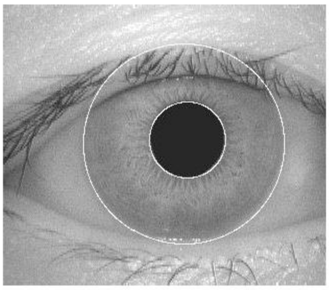

Figure 6. Iris and pupil boundaries

After that, we need to detect and eliminate the eyelash and eyelid using 1D Gabor filters [19].

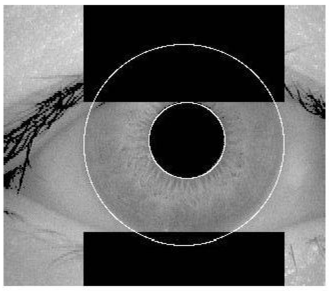

Figure 7. Noise elimination (Eyelid and Eyelash)

2) *Normalization:*

Once the iris region is successfully segmented, we transform it to have fixed dimensions in order to tolerate upcoming comparisons. The dimensional variations between different eye images are generally due to the iris stretching caused by pupil dilation from varying levels of illumination.

The remapping of the iris region from (x,y) Cartesian coordinates to the normalized non-concentric polar representation is modeled using the following formula [18] :

$$\begin{cases} I(r,\theta) = I(x(r,\theta), y(r,\theta)) \\ x(r,\theta) = (R_{pupil} + \frac{r \times |AB|}{20}) \times \cos\theta \\ y(r,\theta) = (R_{pupil} + \frac{r \times |AB|}{20}) \times \sin\theta \\ |AB| = \sqrt{d} \times K \pm \sqrt{d \times K^2 - d + R_{iris}^2} - R_{pupil} \\ d = (x_o - x_{o'})^2 + (y_o - y_{o'})^2 \\ K = \cos(\pi - arctg(\frac{y_o - y_{o'}}{x_o - x_{o'}}) - \theta) \end{cases} \quad \textbf{(5)}$$

I(x, y) is the pixel intensity

O is the center of the iris/pupil boundary and the cartesian landmark reference

O' is the center of the iris/sclera boundary.

A and B are respectively a point from the iris/pupil boundary and an other from the iris/sclera boundary and they have between them an angle θ with the horizontal axe of the cartesian mark.

Figure 8. Figure : Illustration of the normalisation process
Normalized image (left) and Mask of the resulting image (right)

3) *Feature Encoding*

We have here to extract the most discriminating information of the iris pattern and encode their significant features to facilitate templates comparisons.

The generated template requires a related matching metric to measure similarity between iris templates generated from the same eye (intra-class comparisons), and templates created from different irises (inter-class comparisons). These measures should be distinguishable to highlight confidence in judging whether two templates are from the same iris or from two different irises.

For this, we have chosen to encode iris pattern data by 2D Gabor filters using the following equation:

$$G(x,y) = e^{-\pi[(x-x_0)^2/\alpha^2 + (y-y_0)^2/\beta^2]} e^{-2\pi i[u_0(x-x_0)+v_0(y-y_0)]} \quad \textbf{(7)}$$

Figure 9. Figure : Illustration of the feature encoding process
Iris template (left) Mask of the iris template (right)

4) *Matching*

For matching, the Hamming distance was chosen as recognition metric, since bit-wise comparisons were required. This measure informs about the number of similar bits between two bit patterns.

The Hamming distance gives a measure of how many bits are the same between two bit patterns.

$$HD = \frac{\|(codeA \otimes codeB) \cap (maskA \cap maskB)\|}{\|(maskA \cap maskB)\|} \quad \textbf{(8)}$$

- HD is the Hamming distance
- A and B are two normalized iris.
- codeA and codeB are respectively the bit-code of A and B
- maskA and maskB are respectively the mask of noise of A and B

C. *Final Decision*

The proposed approach is based on a couple of modalities recognition: fingerprint and iris, and every part provides its own decision. The final decision of the system will take in consideration both of the last decisions using the operator "AND".

Hence, no body can be accepted unless both of the results are positive. This choice has been taken in order to maximize the system security.

VI. Conclusion

Use of multiple biometric indicators for recognizing persons, known as multimodal biometrics, has been shown to enhance precision and population coverage, while decreasing vulnerability to spoofing. Several studies prove the advantages of multimodal biometrics.

This paper has presented a multimodal biometric approach based on fingerprint and iris recognition and tested using a database of grayscale fingerprints and a database of grayscale eye images. The final decision of the system uses the operator "AND" between decision coming from the fingerprint recognition step and that coming from the iris recognition one.

Hence, no body can be accepted unless both of the results are positive. This choice has been taken in order to highlight the system protection.

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