Knuckle based Hand Correlation for User Authentication

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ABSTRACT

Different hand-derived biometric traits have been used for user authentication in many commercial systems. In this paper we have investigated the possibility of using a new biometric trait - the knuckle for user authentication. Knuckle regions are extracted from the hand images and correlation methods are used for the purpose of verification. Experimental results on a data set of 125 people show that the knuckle is a viable biometric trait, which can be used as an alternative to finger and palm prints or in conjunction with them.

Keywords: Knuckles, correlation, authentication, biometrics

1. MOTIVATION

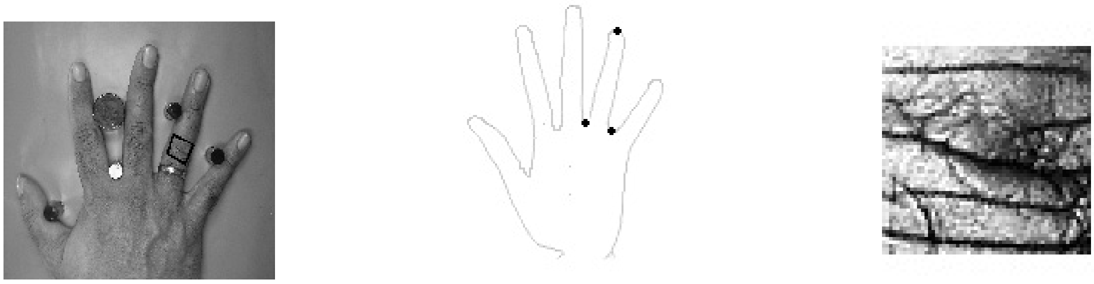
Biometric authentication is gaining more importance in recent years compared to knowledge-based techniques such as identification cards and passwords for security reasons. Different biometric techniques have been developed, each of them having their own advantages and disadvantages, according to user acceptance, cost and accuracy [1,4]. Those that use hand-derived biometric traits are relatively inexpensive to implement and are less intrusive compared to techniques that make use of iris, retina, face and speech. Geometrical features of the hand, Fingerprints and Palm prints are hand-based traits that have thus far been successfully exploited for user authentication [5, 6].

Knuckles of the human hand are characterized by the creases on them. These creases differ from person to person. Knuckles can therefore be used for the purpose of distinguishing human beings, making them a potential biometric trait. Knuckles, being hand-derived, also enjoy the same advantages that other hand-derived traits possess. Knuckles, if a viable trait, can therefore be used as an alternative to fingerprints and palm prints, or in conjunction with them in multi modal systems. In this paper, we have investigated this possibility of using the knuckle as a biometric trait.

In Section 2, the experimental setup for image acquisition is described. Extraction of the knuckle region from the hand image is discussed in detail in Section 3. Section 4 describes the procedure employed for verification. Experimental results are listed in Section 5. The results obtained are discussed in Section 6. The conclusions are presented in Section 7.

2. IMAGE ACQUISITION

The experimental setup used is similar to ones used for hand geometry [7], consisting of a flat plate with five fixed pegs to guide the placement of the hand, a digital camera and a uniform light source. Grayscale hand images of 125 different participants were acquired using this setup, with four hand images per person. Fig. 1a shows an image acquired using this setup. The resolution used is 192 pixels per inch (ppi).



(a) **(b)** **(c)**

Figure 1: (a) Typical hand image (knuckle of ring finger enclosed in black). (b) Contour of hand with three maximum curvature points of Ring finger. (c) Expanded view of the knuckle of the ring finger aligned vertically.

3. FEATURE EXTRACTION

The first step is to segment the knuckle region from the hand images. The knuckle of any of the five fingers can be potentially considered independently for verification. When the hand is placed palm down, the thumb is slightly tilted to one side and thus the thumb's knuckle is not completely visible in the captured image. Therefore, avoiding the thumb, we chose to use the knuckle of the ring finger. One may also consider using two or more fingers independently and make a collective decision to verify the authenticity of the user.

From the captured image of the hand, the contour [3] is extracted using a boundary-tracing algorithm. From the contour, the tip of the ring finger and the two joints at the base of the ring finger are identified, as these are points of maximum curvature [2] along the contour of the ring finger. The contour of the hand and the three maximum curvature points are shown in Fig. 1b. With the help of these three points, the captured image is rotated so that the ring finger is pointing vertically upwards. For locating the knuckle, the ring finger is considered to be a straight line with the center of the knuckle located at three-fifths the length of the finger, from the tip. The knuckle is extracted as a square region of 128 x 128 pixels around the center point. Fig. 1c shows the extracted knuckle region. Though the location and size of the knuckle were chosen heuristically, the point to be noted is that the same region will be identified for each person every time he places his hand for verification. When a user comes in for registration, his hand image is captured, and the 128×128-sized intensity matrix of his knuckle is extracted and stored in the database.

4. VERIFICATION

During verification, the intensity matrix of his knuckle is again obtained as described above. This intensity matrix is cross-correlated with the intensity matrix in the database to obtain a cross-correlation matrix. The cross-correlation matrix is computed for shifts of one pixel up to a maximum shift of ten pixels. The cross-correlation matrix is therefore a 21×21 matrix. This is to account for a possible error of ten pixels in the location of the center point of the knuckle.

For an authentic user, it is expected that the cross-correlation matrix will have a sharp fall-off from the maximum. On the other hand, no discernible fall off is expected in the case of an imposter. The gradient at the maximum value of the cross-correlation matrix is computed to capture this fall-off. This gradient is calculated as the difference between the maximum value and the mean of the neighboring 8 elements. This value of the gradient is used for verification using a suitable threshold.

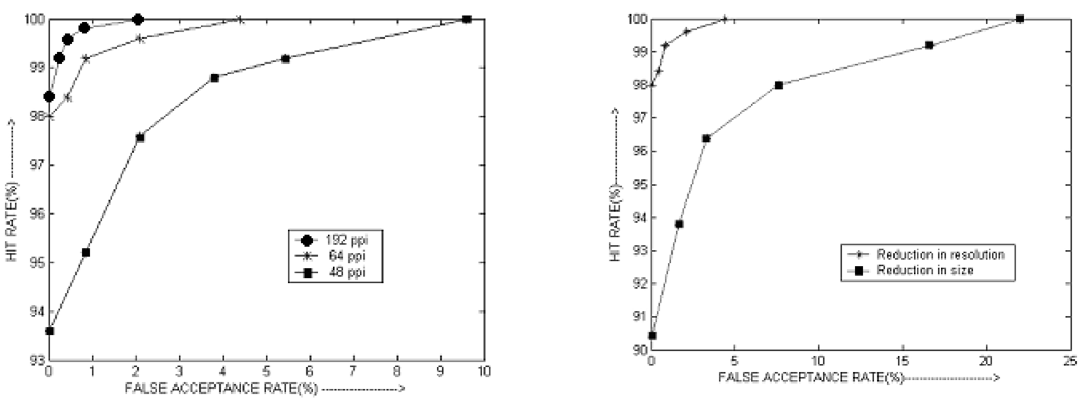
5. RESULTS

There are 4 hand image samples per person. False Rejection Ratio (FRR) [5] values are computed by comparing each of the four samples against the other three; a total of 6 comparisons per participant. False Acceptance Ratio (FAR) is computed by comparing one sample of each of the 125 participants with each of the four samples of 120 other people.

The FAR and FRR values for various thresholds at a resolution of 192 pixels per inch and knuckle size of 128 x 128 pixels are computed. The average Equal Error Rate (EER) is found to be 0.40. The FRRz (FRR at zero FAR) is 1.60, while the FARz (FAR at zero FRR) is 2.08.

At the original size of the knuckle, the resolution was reduced to 64 pixels per inch (reduction by a factor of nine), and 48 pixels per inch (reduction by a factor of sixteen). For these resolutions the average EER values are 0.80 and 2.30 respectively. The FRRz and FARz are 2.00 and 6.64 respectively when the resolution is 64 pixels per inch, and 4.40 and 9.58 when the resolution is reduced to 48 pixels per inch.

Now, keeping the resolution fixed at 192 pixels per inch, we vary the size of the knuckle. For intensity matrices of size 64 x 64 (one-fourth the size) and 42 x 42(one-ninth the size), the average EER values are 1.20 and 3.40. The FRRz and FARz are 2.00 and 9.58 respectively at $1/4^{th}$ the size, and 10.00 and 22.50 respectively at $1/9^{th}$ the size.



(a) **(b)**

Figure 2: Receiver operating characteristics (ROC): (a) ROC curves for three different resolutions with size being kept constant. (b) Comparison of ROC curves for reduced size and resolution by the same factor

6. DISCUSSION

With reduction in size, there is a drastic fall in the accuracy. The creases on the knuckle constitute a majority of the detail available on the knuckle. The creases on the knuckles are widely spaced. On reduction of size, therefore, several creases or parts of creases are omitted. A lot of detail is thereby lost. As a result there is a sharp decline in accuracy on reduction of size of the knuckle. On the other hand, the fall in accuracy on reduction of resolution is fairly small. This is because the creases being widely spaced, on reduction of resolution, the creases will still be discernible. Fig. 2a compares the performance of the system for varying resolutions with size kept constant.

By not reducing the size, and instead opting to reduce resolution, the space required for storage is reduced and at the same time, more detail is retained than would be in the case of a corresponding reduction in size. Therefore, a reduction in resolution must be preferred to a reduction of size of the knuckle if storage space is a constraint. Fig. 2b compares the performance of the system on reduction of size and reduction of resolution by the same factor of 9.

7. CONCLUSIONS

In this paper, a knuckle-based authentication system is proposed and its performance is analyzed. An FRRz of 1.60 and a FARz of 2.08 were obtained for a data set of 125 users using the proposed system. The results obtained demonstrate that the knuckle is a viable biometric trait, and can be used as an alternative to fingerprint or palm print or in conjunction with them in multi modal systems to improve over all accuracy.

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