Multimodal Biometric Verification using the Iris and Major Finger Knuckles

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***Abstract*— The drawbacks of unimodal biometric systems such as non-universality, noisy sensor data and spoofing can be mitigated using multiple biometric traits. In this study, a novel multibiometric system to authenticate users based on their major knuckle finger patterns using four fingers (i.e., little, ring, middle, and index) and iris is proposed. A local texture descriptor namely binarized statistical image features (BSIF) has been employed to extract the features for each of the biometric traits considered in order to improve biometric-based personal verification. The comparison results on PolyU contactless hand dorsal images database and IIT Delhi-1 iris database indicate that the proposed multibiometric authentication with grouping function based score fusion outperforms the existing transformation-based fusion approaches in literature (e.g., t-norms, symmetric-sum), attaining a correct recognition rate of 95.54%.**

Keywords—* *Biometrics; Multibiometrics; Grouping function; Score level fusion; Authentication; Iris; Major finger Knuckles

I. INTRODUCTION

Conventional authentication methods based on identity cards, passwords, PINs, etc proved inadequate to face the growing threats of identity theft and terrorism [1] [9]. Due to the advantages offered by biometrics over traditional authentication methods (e.g., biometrics modalities cannot be stolen or shared, the user does not to carry a smartcard or need to remember a password , etc), biometrics was heralded as a new standard for identity management [9] by replacing knowledge-based authentication with human's physiological (e.g., iris, major finger knuckle patterns, fingerprint, face) or behavioral 1 (e.g., signature, keystroke analysis, gait, voice) attributes. Automated personal verification based on biometrics traits has been increasingly deployed in numerous applications [1] including governments (e.g., passport, national ID card, border control), law enforcement (e.g., forensic applications, criminals identification), and Commercial sectors (e.g., data access, credit cards, network login).

However, human authentication based on a single biometric trait (unimodal system) showed limitations [2] due to the noisy data, poor quality of some biometric modalities, non-universality, deliberate manipulation, and spoof attacks [1]. Towards the purpose of overcoming these limitations and to attain a high level of authentication, fusing information from various biometric sources (i.e., multiple traits, sensors, algorithms) is able to exceed the most above issues related to unimodal biometric systems. The key objective of integrating the human biometric traits in the most security applications is to ensure that no user is able to assume more than one identity due to the difficulty of sharing, stolen or forgotten the biometric characteristics.

The fusion of information in multibiometric systems can be done at different levels [1] : (i) score level, where the authentic and imposter match-scores are combined, (ii) feature level, merging the feature sets of different biometric evidences, (iii) decision level, in this kind of fusion, the decisions from multiple biometric modalities are combined to determine the last decision either the user is accepted as genuine or refused like an imposter. In multibiometric authentication frameworks, the fused performance should exceed the single-modal biometrics. In this study, we aim to explore a multimodal biometric user verification framework using five modalities (i.e., iris and major finger knuckle patterns of little, ring, middle, and index fingers). The choice of these pieces of evidence were due to some reasons. First, apart from the rich information provided by major knuckle finger patterns, these four patterns can be simultaneously collected (i.e., acquiring hand dorsal images). Second, the human iris provide a stable information over time. Third, the combination of five biometric traits makes a difficult to an imposter to spoof all these modalities simultaneously. This study also aims at exploring the integration of matching scores using a novel method for score level fusion namely grouping function.

The rest of this paper is organised as follows. The next section presents a prior works for major finger knuckle and iris. Then, the proposed multimodal biometric human authentication system is explained, which is followed by experimental protocol, experimental results and discussion. The paper finishes with a conclusion.

II. . RELATED WORK

Although major knuckle fingers and iris are widely exploited in biometric systems, there is limited literature on the integration of major knuckle of four fingers (i.e., index, middle, ring, and little) with iris for multimodal biometric verification. However, numerous multibiometric systems were proposed. Bhavani and Rani [3] proposed a Finger-Knuckle

Print (only one finger) and IRIS biometric system based on Linear Discriminate Analysis (LDA) and 2D block based Gabor method for feature extraction, respectively. Aditi *et al.* [4] explored the combination of minor and major finger knuckle pattern for human identification, the Local Binary Pattern (LBP) and Improved Local Binary Pattern (ILBP) have been employed to extract the features. Kumar and Xu [5] presented the fusion of first minor , second minor and major knuckle patterns along with palm dorsal surface to further improve identification performance. Muthukumar and Kannan [6] investigated the discrete wavelet transform (DWT) and Scale Invariant Feature Transform (SIFT) on fingerprint and finger knuckle print images and fuse them at feature level after their clustering using K-Means algorithm. The authors in [7] developed a multibiometric verification based on voice, iris and face. While, authors in [8] proposed a score level fusion of iris and fingerprint based on four score fusion methods (i.e., weighted sum , simple sum , min and max rules).

The purpose of this study is to explore the possibility of fusing Major Finger Knuckle Patterns (MFKPs) of four fingers, i.e., index, middle, ring, and little along with iris, for automated human authentication. It may be noted that MFKPs of four fingers can be acquired simultaneously without any nuisance to individuals, also at lower cost [5]. Therefore it is important to invest the acquisition of five biometric traits using only two sensors. The proposed multi-biometric system was performed using the score level fusion. The features from MFKPs and iris have been extracted applying the same local texture descriptor namely binarised statistical image features (BSIF). Thus, homogeneous features were extracted. To alleviate the problem of the absence of realistic multimodal biometric datasets, we provide an experimental analysis of the proposed fusion scheme on chimeric dataset combined from the benchmark Hong Kong PolyU Contactless Hand Dorsal Images [5] and IIT Delhi-1 iris datasets [9].

III. MAJOR FINGER KNUCKLE AND IRIS AUTHENTICATION.

Owing to the high stability and uniqueness of iris patterns over the lifetime of a person [10][11], the human iris became a very useful biometric research. The iris is the colored region of the eye located between the white sclera and pupil, as shown in Fig. 1. Therefore the iris region must be segmented and normalized before extracting the iris features from an eye image. The standard segmentation technique assumes that the boundaries of inner and outer of iris region are circular and employs the upon radial gradients to detect their location[11]. After the estimation of the iris's boundaries, the iris region is unwrapped into a rectangular block by mapping this region into polar coordinates [11]. To facilitate matching between the iris pattern samples, the size of rectangular block should be normalized before comparison stage.

A major finger knuckle patterns (MFKPs) are formed on the finger dorsal surface joining middle phalanx and proximal phalanx bones [5]. The human finger consists of three as depicts in Fig.2. These MFKPs can either be employed as independent biometric identifier or fused along with other biometric patterns to enhance performance in verifying individual identities. Besides, MFKPs will be very beneficial in forensic applications when MFKPs images are the main available source of information to ascertain the suspect's identity, especially with lack of face or fingerprint information. Enhance biometric-based human authentication using MFKPs imposes accurate segmentation stage of region of interest images (ROI). The key objective in this stage is to generate a fixed size ROI from the dorsal finger images, especially in cases when the age of individuals is different or varying length and widths of fingers. In this work, the employed segmentation setup is similar to as the one used in reference [5].

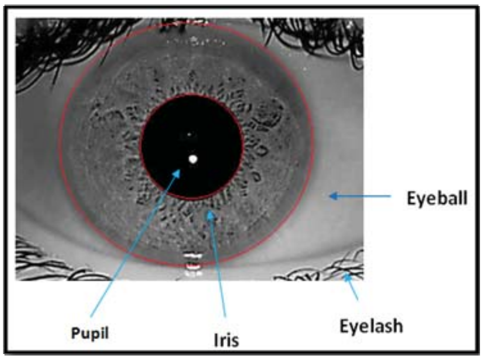

Fig. 1. Terminology of the human eye.

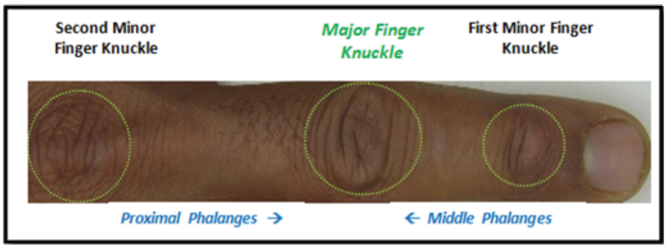

Fig. 2. Terminology of the human finger dorsal image.

A. Binarized statistical image features

The textural local descriptor BSIF has been introduced by Kannala and Rahtu [15]. BSIF computes a binary string for each pixel based on the response of pre-learnt filter. The key objective of this study is to investigate the employ of BSIF for reliable biometric-based personal authentication from major finger knuckle patterns and iris images after previously used for face recognition [15], ear and palmprint based multibiometric recognition [14]. For a given iris or major finger knuckle finger patterns biometric image Y of size $m \times n$ and a linear filter W_i of the same size, the response of filter is obtained by:

$$S_i = \sum_{m,n} W_i(m,n)\, Y(m,n)$$

The binarized feature b_i is given by:

$$b_i = \begin{cases} 1 & if\ s_i > 0 \\ 0 & otherwise \end{cases}$$

Where filters W_i are learnt from natural images via independent component analysis.

B. Grouping functions

Aggregation is the process of integrating numerous values into a single one, which has been employed in many experimental sciences. The function that maps a vector of input values into a single output value is called aggregation function. In this work, we explore matching scores combination using an aggregation function namely grouping function to integrate major knuckle patterns and iris.

The concept of grouping functions were introduced by H. Bustince [13]. These functions are complement of the concept of overlap functions [13]. Grouping functions are a type of binary functions that are employed as a rule of grouping for fuzzy sets. In particular, grouping function is a mapping G: $[0,1] \times [0,1] \rightarrow [0,1]$ which satisfies the following conditions :

(a) G is commutative.
(b) G is continuous.
(c) G is nondecreasing.
(d) G(1,1) = 1.
(e) G(0,0) = 0.

The grouping function utilized in this study is expressed as follows:

$$G(s_1, s_2) = \frac{\max(s_1,s_2)}{\max(s_1,s_2)+\sqrt{(1-s_1)(1-s_2)}}$$

Where S_1 and S_2 are two normalized matching scores

IV. Experimental Protocol

Fig. 3 shows an architecture illustrating the overall procedure of the proposed multibiometric system verification that integrates information from MFKPs and iris biometric sources. To ascertain the claimed identity of an individual, the individual should present his hand and iris to the corresponding sensor. First, hand and iris are processed to extract the region of interest. Then, the segmented images are matched with respective templates stored during the enrolment stage in the database to find the similarity between each two feature vectors. The matching scores obtained from deferent biometric matchers should be first normalized into the same range [0,1] prior to integrating them. Here, min-max normalization [16] was applied as below:

$$S' = \frac{S-\min(S)}{\max(S)-\min(S)}$$

Where S' is the normalized score and S represents the matching score for ith biometric modality. After that, the normalized scores of five individual matchers (iris, major knuckle from little finger, from ring finger, from middle finger, and from index finger) are combining using grouping function. Let S = G(x , y) denotes the combination of two scores based on the proposed grouping function. Let x', y', z', t', and v' the normalized match-scores for the five biometric traits. The two scores C'_1 and C'_2 are first fused to yield G(x' , y') which is in turn integrated further with z' to yield G(G(x', y'), z') until all normalized match-scores are fused. Thus, the fused match-score F can be given as :

F = G(G(G(G(x', y'), z'), t'), v')

Finally, the combined match-score F is compared with a threshold *t*, which assigns an unknown user as genuine if F ≥ *t*, otherwise the user is classified as an imposter.

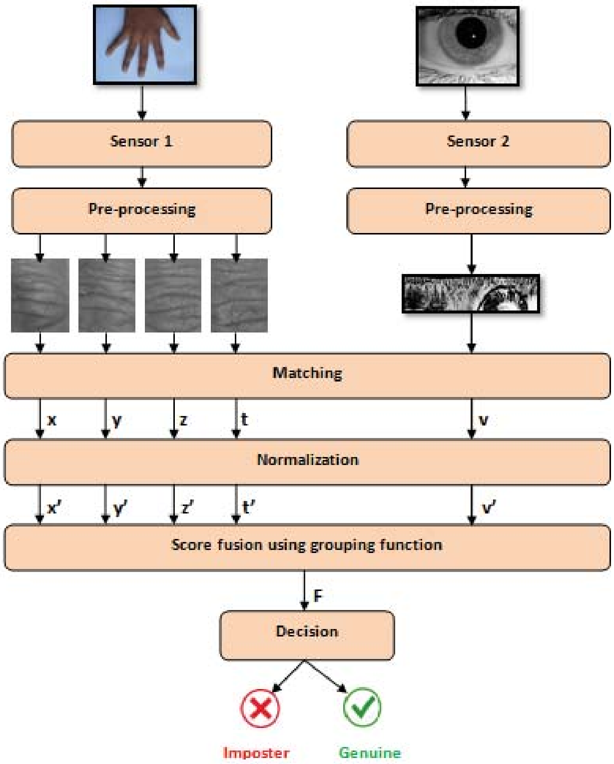

Fig. 3. Architecture of proposed multimodal biometric authentication framework

V. Experiments and Results

In this study, the texture descriptor BSIF has been extracted from normalized iris and MFKPs of four fingers images. It is worth mentioning that iris and MFKPs contain richer information, so combination of these biometric traits is expected to provide better recognition performance over the unimodal systems owing to the existence of diverse source of biometric information..

A. Databases

The performance of proposed multibiometric system was evaluated on our own chimeric database due to the lack of MKFPs-iris multimodal database.

To construct the chimeric database, we have used the iris images from IIT Delhi-1 iris datasbase [10]. The images were collected from the staff and students at IIT Delhi campus, India. The 2240 images were acquired from 224 different users, i.e., 176 males and 48 females aged 14-55 years. It may be noted that all iris images were acquired in the indoor environment with resolution of 320 x 240 pixels. The Majority of these images were acquired from the left eye except some images were acquired from right eye. In addition to the iris original images, 432 x 48 pixels normalized iris images are also included.

The second used database in our experiments is the Hong Kong Polytechnic University Contactless Hand Dorsal Images Database [6]. The images were collected in the Hong Kong polytechnic university campus, in IIT Delhi campus, and in some villages in India. The database contains images of 712 subjects. Besides, segmented and norma-lized images of minor, second, and major knuckle of little, ring, middle, and index fingers along with resized dorsal images are also included. we only used images for major knuckle.

B. *Experimental results*

The grouping function based-biometric score fusion scheme is evaluated based on a virtual multimodal biometric dataset that consists from little, ring, middle, and index finger's major knuckles of 224 users and the irises of another 224 users of iris. Thereby the dataset has virtually 224 users, 2 images per-user, out of which one image to build the enrolled template and one image for testing in order to investigate the combination of these modalities in more realistic scenarios, when only one enrolled template is available for each person. Therefore we have 224 genuine scores and 49952 (224 × 223) imposter scores for each of the biometric trait considered.

The performance evaluation of the proposed biometric-based authentication is reported in Receiver Operating Characteristics (ROC) curves. The ROC curve is drawn GAR vs. FAR where GAR = 1-FRR is the genuine acceptance rate. FRR (False Rejection Rate) is the proportion at which genuine individuals are rejected by the system as imposters, FAR (False Acceptance Rate) is the proportion at which imposter individuals are accepted by the system as genuine users, and GAR is the rate of the genuine users accepted over the total of enrolled individuals.

Fig. 4 displays ROC's of unimodal biometric authentication and of their integration by using grouping function at score level fusion on proposed virtual multimodal dataset. At FAR equals 0.01 percent, the GARs of iris, index's major knuckle, middle's major knuckle, ring's major knuckle, and little's major knuckle are: 89.23%, 40.00%, 45.50%, 51.40%, and 14.00% respectively. But with grouping function GAR of 95.54% is achieved with the same FAR. The performance achieved by score level integration strategy using symmetric sum proposed in [16] was reported. In addition, we also report the results attained by using Schwizer & Sklar and Einstein product *t*-norms [12], min and max rules [8], and weighted sum [9]. From table 1, we can observe that proposed score level fusion using grouping function outperforms the existing popular approaches in the literature.

Table 1: Performance of the proposed multibiometric system fusion using various approaches.

Score level method at FAR=0.01%	GAR(%)
Max rule [8]	43.30
Min rule [8]	62.30
Weighted Sum [9]	93.42
Schwizer & Sklar *t*-norm with p = 0.5 [12]	83.80
Einstein product *t*-norm [12]	84.00
S-sum using Max rule [16]	85.75
S-sum using Min rule [16]	93.70
Proposed Grouping Function	**95.54**

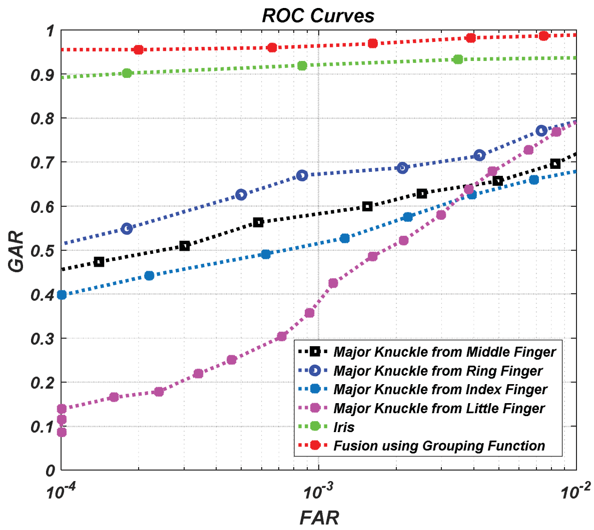

Fig. 4. ROCs of individual biometric traits (iris, index's major knuckle, middle's major knuckle, ring's major knuckle, and little's major knuckle) and their combination using grouping function

VI. Conclusion

In this study, we presented a multimodal biometric framework for ascertaining the identity of users based on their iris and major finger knuckle patterns. The experiments on a chimeric database (i.e., the iris images have been selected from IIT Delhi-1 iris database, whereas MFKPs have been selected from the contactless hand dorsal images of PolyU database) confirmed that proposed multibiometric framework using grouping function achieves better recognition compared to unimodal iris and MFKPs biometrics as well as their combination using other existing biometric score fusion methods such as symmetric sum, *t*-norms, min and max rules, and weighted sum. Apart from the good authentication achieved using grouping function, these grouping functions are computationally fast. In future, we aim to evaluate the robustness of the presented multibiomeric framework against spoofing attacks.

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