Original Research Paper

A Proposed Integrated Human Recognition for Security Reassurance

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Abstract: A lot of systems require reliable and thorough authentication to ratify individual's claimed identity, especially in national and international security and defense. Unibiometric system suffers inherent weaknesses that are unavoidable in the system. Such inadequacies may directly or indirectly lead to an unacceptable error. For this reason, researchers pay great attention to the more advanced biometrics (referred to as multimodal biometrics). A multimodal biometric system involves at least two unimodal traits in a sole identification. This alleviates some of the drawbacks and improves recognition accuracy despite number of population considered. This research proclaims a new technique of integration for human recognition improvement using four physiological characteristics: Face, iris, palmprint and thumbprint. In addition, two fusion strategies namely, score-level and decision-level are presented using robust algorithms. The multimodal biometric systems possessed relative merits or pluses over its counterpart monomodal biometrics. The higher biometric modalities are integrated the more system is secured, hence better security assurance. Therefore, successfully conducting our research can derive supreme benefit over conventional multimodal biometrics. The integration results to outstanding gap coverage for security reassurance.

Keywords: Unibiometric, Multimodal Biometric, Integrated Human Recognition, Security Reassurance

Introduction

Biometrics is essentially a pattern recognition system (Ghandehari and Safabakhsh, 2011), which uses physiological and behavioral characteristics of a person; physiological characteristics may be fingerprint, iris, face or hand geometry (Bhattacharyya *et al*., 2009) and behavioral characteristics may be voice, signature, or other keystrokes dynamics. Human recognition is primarily used for verification or identification of an individual, for the purpose of security or authenticity. The recognition is either through the physiological or behavioral characteristics to ratify person's claimed identity. The application of statistical or structural techniques in analyzing those biological circumstances is referred to as biometric system or simply biometrics.

Single biometrics suffers limitations (Ross *et al*., 2006) such as lack of uniqueness, non universality of the chosen biometric trait and noisy data. Moreover, a single biometric often fails to be accurate enough for identification of large users and sometimes physical characteristics of a person for a selected bio metric might not be available or readable (Ko, 2005). Consequently, multimodal biometrics was introduced. The multimodal biometrics is simply combining two or more biometric features in a sole identification to achieve greater accuracy (Ko, 2005; Aggarwal and Gulati, 2012). Therefore, even if one modality is partially disturbed the other leads to an accurate identification. Multimodal system can eliminate these problems (Yang *et al*., 2007) and drastically minimize spoofs attacks; hence, improves the performance upon single biometrics (Jiaqiang *et al*., 2013). Biometric fusion can be combined at different levels viz. at data-sensor level, feature extraction level, matching-score level and decision-level (Ross and Jain, 2013; BWG, 2009). The justifiable reason of combining the two or more modalities is to improve the recognition accuracy (Aggarwal and Gulati, 2012) and overcome other limitations of single biometric systems (Nandakumar *et al*., 2008).
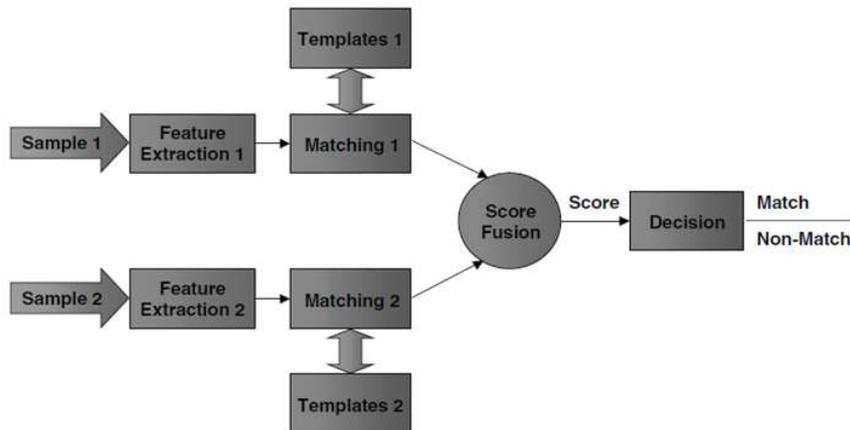
Fig. 1. Block diagram of multimodal system with score-level fusion (Raytheon, 2005)

In general (Imran *et al.*, 2013) the fusion process enhances the system precision significantly which simply endorses well established fact about multimodal system.

In this study, the writers started with reviews of existing literature within previous decade, starting with single biometrics, further to a bimodal or pair wise biometrics and down to a tri-modal or compound biometrics. Significant improvement of multimodal biometrics over traditional, various methods of fusion, different fusion strategies and normalization practices and databases used where possible were reported in the review. Moreover, the paper covered mainly those reviews pertaining physiological characteristics of biometrics. Referring to the existing literature, there exist several integrated biometric schemes by various authors in the field of pattern recognition, employing different algorithms comprising; appearance based and texture based algorithms, neural network among others. Additionally, an integrated approach based human recognition for security reassurance is proposed. The multimodal biometric systems use various levels of fusion to combine two or more modalities (He *et al.*, 2010).

Sensor Level: Fusion at the sensor level combines the two images from different sensors. Feature Extraction Level: Fusion at the feature level concatenates the features extracted using two or more modalities (Imran *et al.*, 2013). Matching Score Level: Fusion at the matching score level combines the scores which describes the similarities of biometric traits acquired and their templates obtained by each biometric system. Or simply where the matching scores obtained from multiple matchers are combined. Decision Level: Fusion at the decision level combines the decisions taken by each biometric system, to obtain a final decision (Deriche, 2008) or simply where the accept/reject decisions of multiple systems are consolidated (Imran *et al.*, 2013).

The flow chart depicting the multimodal system with score-level fusion is shown in Fig. 1.

The main reason of fusion these biometric traits is that, a system of highly demanding restriction such as border crossing control, national and international security and defense, need to systematically secure and guarantee user's absolute identity. Therefore, the main aim of this study is to cover an outstanding gap in multimodal biometric identification that will be used in the aforementioned areas. Thus implementing this system, can work efficiently for ensuring the security of systems.

The rest of the paper is organized as follows: Section 2, illustrated the review works of current biometric applications. The reviewed study is discussed in section 3. The proposed integrated approach is introduced in section 4. Conclusions and future scope are drawn in section 5.

Review Works of Current Biometric Applications

A number of biometric systems exist in various applications; each constitutes its strengths and weaknesses. Multimodal biometrics, as a successful application of biometric technology has recently receives significant attention by researchers to reveal new algorithms and efficient fusion techniques. In this section, several articles are investigated on conventional and modern approaches to biometrics; some of these literary works are categorized below:

Single Modal Biometrics

Single or sole biometrics involves the use of only one feature or biometric trait to form the recognition. It is the commonest biometric system exists in the literature and receives researchers' interest most, until now when trend of higher order biometrics supersedes. Few reviews under this category are described.

Kaur *et al.* (2010) discussed a novel method of enhancing iris recognition by reducing complexity and increasing algorithm speed. The overall computational time was reduced from 7.016 to 1.109 sec and reliability was also increased. Canny edge detection was used to generate an edge map and circle detection algorithm was used for iris localization. The iris was normalized, enhanced using local histogram equalization and filtered using Gaussian filter. For the feature extraction, cumulative sum based analysis method employed; finally Hamming Distance (HD) compared the similarity between the two iris codes during feature matching. The method reported accuracy of 99.38% and low FAR.

Asadi *et al.* (2010) compared the performance of face recognition using Principal Component Analysis (PCA) and Cross-Correlation Technique. Euclidean distance was used to find out the distance between two images. However, a database of different image sets of faces was constructed using two dimensions so that the covariance matrix will be 2×2. The face images of 12 people with different poses (48 images) were taken for testing. The recognition accuracies of PCA and CCA were 90% 85% respectively.

Zhonghua and Bibo (2010) proposed a method which recognized iris using Coefficients of Morlet Wavelet Transform, to enhance the efficiency of iris recognition and reduce complexity through iris localization, normalization for effective iris region. Different iris patterns were classified using pattern matching. A sum of 567 images from 81 subjects was used from CASIA iris database. The correct recognition rate reported using this method was 99.946%.

Ghandehari and Safabakhsh (2011) evaluated the recognition performance of palmprint using statistical PCA and Adaptive Principal Component Extraction (APEX) method. The two algorithms were used to extract the principal component of the palmprint of 3000 palm-gray scale images on 300 users obtained from Hong Kong Polytechnic University (poly U.) palmprint database. Ten images were collected in two sections five for each section within interval of two months. The outputs were classified using Euclidean Distance (ED) and Hamming Distance (HD). The latter yielded better results than the former and APEX was reported to be faster.

Yanxia and Qiuqi (2006) demonstrated palmprint recognition system using Kernel Fisher Discriminant Analysis (KFDA) to extract higher order palmprint features for recognition. The work developed a scanner-based device that requires no fix pegs. KFDA was used to convert the nonlinear relations of input data and FLDA (fisherpalm) detected the linear relation and discriminate input features. The experiment considered ten images of both hands per individual and conducted on 80 people. KFDA was shown to be more effective than PCA (eigenpalms) and FLDA particularly with only few training samples.

Jacey-Lynn and Duncan (2011) investigated three-dimensional face (3D) and facial expressions using Tensor based Multivariate Statistical Discriminant (TMSD) model, which employs multi linear algebra. The SUNY Binghamton 3D database from 100 subjects each with seven different facial expressions; neutral, anger, disgust, happiness; sadness, fear and surprise were considered. The face surfaces were preprocessed to produce a more robust recognition result. Euclidean distance scheme was finally used. The results of TMSD performed far better than PCA approach.

Samadi and Pourghassem (2013) introduced a practical algorithm for children faces classification from adults' using standard FG-NET database containing 1002 facial images of 82 different subjects, 411 and 591 were children and adults respectively. The faces were detected, landmarked and preprocessed. Statistical model of the face was carried out using face model parameters, LDA extracted the useful facial features from the model which resulted into a feature space, practically included the difference between adult and child. Lastly, Euclidean distance discriminant function categorized a child or an adult. Accuracy of 85% reported.

Wang *et al.* (2013) assessed images quality of palmvein and palmvein recognition with distance variations from the camera, also investigated the structural differences and clarity of Region of Interest (ROI) image and matched the result when palm changes from 3-8 cm. The palmvein ROI was evaluated using energy gradient function tenengrad. The results indicated that while palmvein becomes larger, the difference of image clarity and structure increases. FRR also increases.

Ahmad *et al.* (2011) compared face recognition using statistical and neural network techniques considering two parameters: Accuracy and recognition time. The paper explored Feed Forward Back Propagation-Neural Network (FFBP-NN), Generalized Regression Neural Network (GRNN), discriminant analysis and PCA. The experiments were conducted on ORL database containing 400 images from 40 persons, ten images per one, 13 females and 27 males. The neural network was proved better performance than the statistical.

Sangram and Davinder (2011) studied fingerprint recognition based on minutiae extraction process, involved preprocessing (i.e., image enhancement and image segmentation) and minutiae extraction. This was followed by minutiae-based matching technique, on the number of minutiae pairings between two finger prints to decide if finger matched or not. The input fingerprints were taken from FVC29004 database, the verification rate of the algorithm displayed about 65-70%. FRR and FAR values were 30-38% approximately.

Pair Wise Biometrics

Pair wise or bimodal biometric requires two biometric modalities to establish authentication or verification and to enhance improvement over single biometrics. Bimodal biometrics is very common in the literature; the performance can be improved by using efficient hybrid algorithms. Few reviews under this category are described.

Park *et al.* (2011) suggested a multimodal biometrics recognition system using fingerprint and vein. The approach used Local Binary Patterns (LBP) for fingerprint based on minutiae points and finger vein. Decision-level fusion of the fingerprint and finger vein was adopted. The result was reported having FAR of 0.019999% and FRR of 1.07%. Significant improvement been achieved over single biometric system.

Ashraf *et al.* (2010) introduced a multimodal biometrics for face and fingerprint using Uniform Local Binary Patterns (ULBP) and minutiae extraction respectively. The format used matching score-level fusion for final recognition and obtained 99.4% accuracy. Individual result depicted 80% accuracy for the fingerprint and 97.6% for the face. The results were quite satisfactory.

Conti *et al.* (2010) created multimodal biometrics integration of iris and fingerprint using frequency-based approach and hamming distance based matching algorithm to achieve a unified homogeneous biometric vector. The paper adopted template-level fusion method and Log Gabor algorithm based codifier was used to obtain a unified template of both the fingerprint and the iris. For the similarity index computation HD was employed. Several results were achieved: Using FVC 2002 DB2B fingerprint database and randomly extracted same-size subset of BATH iris database. FAR = 0% and FRR = 5.71% were observed. In addition, using BATH and FVC 2002 DB2A another interesting working point of FAR = 0% and FRR = 7.28%/9.7% was reported.

Wang *et al.* (2013) suggested a feature level fusion of face and palmprint using Canonical Correlation Analysis (CCA) and PCA for dimension reduction. The combined canonical correlation characteristics were extracted before the features were normalized to eliminate unbalance. Euclidean distance was used for recognition. The experiment was conducted on ORL face database and poly U multispectral palmprint database. The paper also compared the performance of PCA, other fusion techniques: Serial rule, sum rule, weighted sum rule and complex field with the proposed method. The new method showed lowest EER.

Tekade (2012) discussed a multimodal recognition of face and ear using feature fusion of average rule and PCA scheme. 400 face images from ORL database and 375 images from IIT Delhi ear database were utilized.

Fisher linear discriminant analysis was used for feature extraction of the face and the ear separately whereas Euclidean distance for comparison. The paper compared the results of average rule and that of PCA fusion algorithm. PCA acquired better performance.

Xu *et al.* (2013) Initiated a novel joint face and iris multimodal biometric recognition using Contourlet Transform (CT) and two directional two Dimensional $(2D)^2$ PCA. The former was used to extract the iris feature and the latter to extract the face feature. The experiment was conducted using AR face database and CASIA iris database. The proposed joint method outweighed the performance of the single face and iris modal, under all varying conditions of training and Testing Sample Ratio (TTR).

Ahmad *et al.* (2010) evaluated a multimodal system for face and palmprint recognition. Gabor based image processing was utilized to extract discriminant features, while PCA and LDA were used to reduce the dimension of each modality. The multimodal fusion at feature level of face and palmprint produced better recognition result (99.5%) compared to single modal biometrics method (94% for fisherpalm 87% for eigenfaces, 92% for fisherfaces and 91.5% for eigenpalm).

This recent paper by Imran *et al.* (2013) was an addition to their earlier paper in (2010). They reintroduced a multimodal biometrics based on fusion of face and palmprint modalities at all levels of fusion and different fusion strategies using popular appearance based algorithms and texture based feature extraction algorithms. LDA and LPQ algorithms were selected to extract the features of face and palmprint respectively. The experiments were conducted on AR face database and poly U. palmprint database under clean and noise conditions and several observations were made as we will later see in our discussion.

Deshmukh *et al.* (2013) proposed a biometric authentication system based on feature level fusion of face and fingerprint using Gabor filter bank to extract the features independently. PCA and LDA were used for dimension reduction and discriminating enhancement. Distance classifiers authenticate the results. The performance was expressed using ORL face database and FVC 2002 fingerprint database. The proposed system reduced FAR and FRR to 0.35 and 0.75% respectively and achieved recognition accuracy of 99.25%.

Faten *et al.* (2013) set up a bimodal biometrics which integrates face and fingerprint for user identification using Gabor wavelet. It was conducted on ORL face database and FVC 2004 fingerprint database. PCA extracted the eigenvectors for the face recognition and minutiae technique for the fingerprint. The multimodal reduced equal error rate and enhanced performance over single biometrics.

Compound Biometrics

Compound biometrics involves more than two evidences presented by different traits belongs to a user to form their identity as a whole and enhance authenticity efficiency. Although the system might be complex and cost higher due to the requirement of new sensors and longer time during recognition. Consequently, the performance can be significantly improved by utilizing more than one trait for a sole recognition. To the best of the authors' knowledge triple biometrics (where three biometric modalities are considered) is the highest biometrics exists in the literature. Few reviews under this category are described.

Hanmandlu *et al.* (2010) investigated a multimodal biometric system based on hand traits namely, hand geometry, palmprint and handveins at score-level fusion using t-norm strategy. The experimental results discovered that the score-level approach using t-norm rendered fairly good performance and did not require any iteration. The proposed fusion using Hamacher t-norm yielded Genuine Acceptance Rate (GAR) of 99.9% at FAR of 0%. Therefore, good improvement over individual biometrics was observed.

Vivek *et al.* (2012) Described feature extraction techniques of fusion fingerprint, iris and face using Gaussian Mixture Model (GMM). Expectation Maximization method was used to obtain the parameters needed to implement the GMM. The fingerprint was extracted using minutiae technique. For the iris, segmentation, normalization and feature encoding were accomplished. For the face PCA was used. The fingerprint, iris and face images were collected from FBI, poly and Sino biometrics database respectively and information were fused at match score-level using a density based score level fusion. GMM gave superior results.

Yaghoubi and Eliasi (2011) proposed a multimodal biometrics using face, ear and palm based on feature extracted from visual cortex, achieved through transforming face and palmprint images with Gabor filter and ear images with Gaussian filter in HMAX method. However, matching score level fusion was employed. The classification was done using K-NN and SVM classifiers and the experimental results showed 96% accuracy rate on ORL face database, 94% accuracy rate on USTB Ear database and 96.6% accuracy rate on POLYU Palm database. Recognition time was not mentioned which is another major concern in multimodal system.

Dinakardas *et al.* (2013) presented a multimodal identification system based on face, fingerprint and iris. Performance of two different models on these biometric traits was evaluated. The experiments were conducted on a real database consisting 500 persons. The first model extracted fingerprint and iris features using PCA while face using fisherfaces. The second model extracted fingerprint using minutiae approach, iris using LBP and maintaining fishefaces for the face. The results were depicted under ROC curve, standard deviation and 95% confidence interval. The single classifier approach of minutiae based fingerprint extraction and LBP based iris extraction depicted better result than when PCA was used. The multimodal classifier configuration of the second approach outperformed the first.

Imran *et al.* (2011) introduced a new hybrid approach multi biometrics of fusion face and iris using three algorithms: Independent Component Analysis1 (ICA1), PCA and Local Phase Quantization (LPQ) based on different level of fusion. It also discussed comparative analysis of the proposed method with multi-algorithmic and multimodal approaches. The results from the experiments were based on considering all level of fusion excluding sensor level and conducted on ORL-face, CASIA-iris and FVC-2006 fingerprint database. The performance was compared using EER and the proposed hybrid method outperformed the other approaches.

This paper of Xiuyan *et al.* (2011) is based on multimodal biometric of hand vein, iris and fingerprint. Theoretical and experimental studied were compared. Mathematical model of matching score was deduced and score normalization algorithms were analyzed and particularized. Simple Average (SA) and Weighting Average (WA) fusion algorithms were analyzed too. The biometric recognition experiments were assessed on TJU hand vein database, CASIA iris and fingerprint database to verify the fusion theory. The results indicated that the experiments data were consistent with the deduced theoretic results.

Yazdanpanah *et al.* (2010) instigated a multimodal biometric identification system based on features extracted from three biometric modalities including face, ear and gait using Gabor and PCA. Fusion at matching score was performed on ORL face database, USTB ear database and CASIA gait database. The paper evaluated three different kinds of normalization techniques experimentally and two kinds of fusion methods. Z-score method of normalization combined with weighed product method of fusion gave the best recognition performance of 97.5% at 0.1% FAR. The innovative approach outperformed the unimodal systems on a variety of image databases.

Ko (2005) investigated different levels of fusion and fusion strategies that can be adopted in multimodal biometrics. Meanwhile the possible scenarios in multimodal biometric system using finger, face and iris recognition and how they affect the overall identification accuracy were discussed. The need of staffing levels to properly operate the system was also mentioned.

Chaudhary and Nath (2009) suggested a multimodal biometric recognition based on fusion of palmprint,

fingerprint and face at matching score-level. The fusion module performed score normalization using min-max rule before the three normalized scores with their individual weights were combined into a total score by sum rule. The total scores was passed to the decision module and finally declared a person as genuine or an impostor. Both the existing biometric system and the multimodal system were plotted on Genuine Accept Rate (GAR) against False Accept Rate (FAR). The proposed system gave better performance.

Yang and Ma (2007) developed a new fusion technique of identifying fingerprint, palmprint and hand-geometry. The work proposed the use of feature fusion and matching score-level fusion for the identification. The former fused fingerprint and palm-print to form a Joint Feature Vector (JFV) and the latter fused the JFV and the hand-geometry. The qualities of the images were measured using Wavelet Scalar Quantization (WSQ) method. The experiments were realized using Mat lab language and tested on a database of 98 persons. The result proved the feasibility of the approach and this method was highly investigated.

Discussion and Comparison of Techniques

In the enhanced iris recognition method by (Kaur *et al.*, 2010) using cumulative sum based analysis method, substantial accuracy improvement was witnessed over the existing method and achieved FAR of 0.01 compared to 0.05 in the previous one and excessively reduced overall operating time. Fingerprint extracted based on minutiae process obtained verification rate of 65-70%. The low recognition rate was due to inefficient algorithm used and poor quality of images in the database (Sangram and Davinder, 2011). APEX which is one of the PCA techniques involving neural network, though affected by initialization of the network but was more efficient than statistical PCA especially with HD. However, the recognition performance was increased with increased in training samples in both the algorithms (Ghandehari and Safabakhsh, 2011). The statistical model algorithm mentioned in (Wang *et al.*, 2007) for children faces classification showed good result despite classifying images that were opaque. Meanwhile, when neural network classifier was applied (Samadi and Pourghassem, 2013) with different amount of specifications to discriminate child faces, the result was not bettered. The proposed approach for fusion of face, ear and palm illustrated in (Yaghoubi and Eliasi, 2011) showed great performance using score-level fusion and SVM outclassed KNN. The recognition rate of KFDA and FLDA were much higher than PCA whereas FLDA (fisherpalms) performed lesser than KFDA because it cannot describe complicated nonlinear variations such as rotation, movement and stretching variations of hands, but it was a good feature selector since increasing the

number of training samples, fisher palms recognition rate approaches KFDA closely (Yanxia and Qiuqi, 2006). Consequently, FLDA needs to be verified using dissimilar large samples. The performance of TMSD and PCA were compared using Euclidean distance scheme for recognition. The advantage of this classifier is its high speed (Samadi and Pourghassem, 2013). PCA (represents the principal axes of variations across the face) while TMSD (locates the principal axes of variation across various facial expressions and reports the various expression factors related to one another). The recognition of the former surpassed the latter. The low recognition rates for faces with surprise expressions were due to the extreme geometric changes. The proposed method was not effective at distinguishing facial expression that appears similar, such as anger and disgust, fear and surprise as excerpted from (Jacey-Lynn and Duncan, 2011).

Identification of face, fingerprint and iris in Dinakardas *et al.* (2013), LBP based iris extraction couple with minutiae for fingerprint displayed better result than the use of PCA in their feature extractions. Conversely, PCA was used for dimension reduction with canonical correlation analysis in Wang *et al.* (2013) and better performance reported. Also when PCA scheme and average rule were used for feature level fusion with LDA as feature selector in Tekade (2012), the PCA outweighed the average rule and better performance reported. The paper by Wang *et al.* (2013) only emphasized extraction of good quality image in contactless recognition so that each user can simply raise their palms closer to the scanner, no experimental results for comparison of the distance variations results of palmvein recognition. On the other hand, Yanxia and Qiuqi (2006) avoided inconveniencing user by developing a scanner-based device which makes no use of fix pegs; this idea is more cogent and can be practically implemented. It was evidently shown in Ahmad *et al.* (2011) on face recognition that GRNN performed best, followed by Discriminant Analysis (DA), PCA, BP-NN in this order and in terms of consumed time during recognition, DA was proved to be the best technique. Among the popular appearance based algorithms (PCA, LPP, ICA1, LDA) LDA was discovered best for face and among the popular texture based feature extraction algorithms (LPQ, LBPV, Log-Gabor) significant improvement was observed by LPQ for palmprint in (Imran *et al.*, 2013). Similar efforts by the same authors in (2011) LPQ, PCA and ICA1 were selected for their new hybrid method and the performance measured in terms of EER. Additionally when wavelet decomposition scheme applied at sensor level fusion, the performance was not satisfactory, it was even worse than the unimodal counterparts. The bad result was presumed since fusion at the sensor level or feature level is not always possible due to the

heterogeneity or incompatibility of the information content (Jain and Arun, 2007) and fusion at feature extraction level is difficult because feature vectors which are used by different biometric traits may be inaccessible or incompatible (Yazdanpanah *et al.*, 2010). Although after these claims, there were many research on feature fusions which were successful, some reported in this study. In any way, due to easily accessing and easily integrating, fusion at matching score level is generally preferred.

Normalization includes mapping the scores obtained from each modality into a common domain. A good normalization method should be robust and efficient. Z-score outperformed Min-max and Median-MAD normalization techniques in that paper and obtained excellent recognition, so also the weighted Product which involves higher computational cost performed better than the weighted sum. At the same time, the Z-score normalization and tanh normalization scheme were reported having similar performance under clean data, though tanh normalization scheme obtained robust result when corrupted with noise. Z-score model is the most commonly used at present, this kind of model uses the arithmetic mean and variance of the given data to normalize the element in the set. The mean value is 0 and the standard deviation is 1 after the normalization. The fusion performed at score-level, adopting the sum rule, obtained great results under both clean and noise conditions and it was mentioned that the results may vary based on type of feature extraction algorithms employed. Feature level fusion strategies of min-max and Z-score showed minimum EER with Z-score.

Face and palmprint is preferable in many multimodal biometric applications. The score level fusion of face and palmprint adopting the sum rule obtained best results compared to min score and max score rules. In the 'Sum rule' the contribution made by individual matcher will be considered for decision making. In slightly similar way, a weighed sum rule which is one of the parallel fusion methods performed better than ordinary sum rule in Wang *et al.* (2013). Progressively, coming to decision level fusion, 'OR rule' outperformed 'AND rules' in many literatures. It is primarily due to the reason that if any one of the matchers classifies a test sample genuine, the decision will be regarded as genuine. The theoretical significance of multimodal biometric recognition based on classic fusion algorithm at feature matching level was described in Xiuyan *et al.* (2011), since most of the existing literatures were reintroducing fusion algorithm and verify their novel method by experiments again and again.

Significance of the Study

The major aim of reviewing the literature is to arrest the failure of single biometrics, the insufficiency of pair

wise biometrics and improve triple biometrics, since many studies have recommended multimodal biometrics for current and future applications. Multimodal biometric systems own ability to withstand spoof attacks, while single biometric sometimes fails to extract adequate information for verifying the identity of a person. Due to the presence of multiple, fairly independent pieces of evidence, multi-biometrics are expected to be reliable (Jain *et al.*, 2004) and enhanced performance reliability could be achieved by combining multiple modalities. The biometrics test studied in NIST (2002) has revealed that, to achieve acceptable identification accuracy for large user applications multimodal biometrics is required. The justifiable reason of combining the two or more modalities is to improve the recognition accuracy (Ko, 2005) and that is very possible when features of independent biometrics are statistically combined. Combining different modalities produces a system which can outperform single modalities (Kittler and Hojjatoleslami, 1998).

Several methods have been proposed by researchers, on the multimodal biometrics, such methods were reported to have significance improvement over traditional biometrics traits. The performance of a system can be improved by utilizing more than one trait (Ravi and Dattatreya, 2013), though the cost of the system is substantially higher due to requirement of new sensors (Hanuma, 2011). The application of higher integrated biometric system in a highly security demanding applications will be remarkable. The higher the number of features integrated, the more system is secured, hence better system protection. Therefore, successfully conducting our research can derive supreme benefit over conventional multimodal biometrics.

Another reason for carrying out the review in the previous section is to allow the writers choose the best algorithm for their proposed approach, since the aim of any biometric system is to improve recognition accuracy. This is normally achieved by comparing different existing algorithms on a specific problem and selects the best among (Imran *et al.*, 2010). But selecting the best algorithm is not an easy task, because an algorithm may work under certain condition, but not suitable or compatible on another condition or problem. In addition, no algorithm ever exists without any limitation. LDA is the most dominant algorithm for feature selection in appearance based method, it yields an effective representation that linearly transforms the original data space into a low-dimensional feature space where the data is well separated (Mohammed and Gupta, 2013). The dataset selected should have larger samples per class for good extraction of discriminating features. Under the test and comparison of performance of appearance based statistical methods on colored face images in (Önsen, 2003) LDA surpassed ICA under different illuminations and more sensitive than PCA

and ICA on partial occlusions. LDA has small size problem when dealing with high dimensional data (Swets and Weng, 1996). It defines a projection that makes the within-class scatter small and the between-class scatter large (Belhumeur *et al.*, 1997) and trying to find non-linear correlation models among different biometric features can improve the system and recommended that, the intra-class correlation for different feature set should be further explored on extended biometric data sets (Soviany and Puscoci, 2013).

The four physiological biometrics employed in our research have receive significant benefit, since palmprint is user friendly, robust and accurate. Iris texture is unique even for twins. Fingerprint and face have been reliable methods as reported in lots of literature. The model provides an understanding ground between the users and system providers, since the users' identity are totally secured. High priority of the system is; the model will effectively be applied to a real world problem in order to ease security personnel and improve efficiency of identification, by disallowing any fraudulent act.

Proposed Technique

The study proposed a new integrated biometrics approach using four different modalities namely, face, palmprint, iris and thumbprint applying two fusion strategies of score-level and decision-level. Appearance based techniques will be used as feature selectors. The result of the feature extraction called feature vectors are fed into the separate matching modules. Each matching module compares the feature vectors against the database using Euclidean distance classifier, to measure the similarities between the test vectors and the reference vectors in the gallery.

The pair matched scores of the bimodal outputs of iris and thumb, face and palm are regularized using Z-score normalization scheme. The normalized scores are combined into total scores at fusion modules 1 and 2 using weighted sum rule. These are fed to the separate decision modules 1 and 2, where the scores are classified as correlated or uncorrelated using cross correlation analysis and rule is applied at final decision-fusion so that both matchers have to deem the test samples as genuine to classify a person as genuine otherwise as an imposter.

This is computed by comparing these final scores with a threshold. The novelty of this approach is the quadruple biometrics integration, using robust bi-fusion techniques and deducing a mathematical modeling of integration to check the consistency of the experimental figures. To the best of the writers' knowledge, there has never existed such approach in the literature.

The framework of the proposed multimodal biometric system based on matching score and decision-level fusion is shown in Fig. 2.
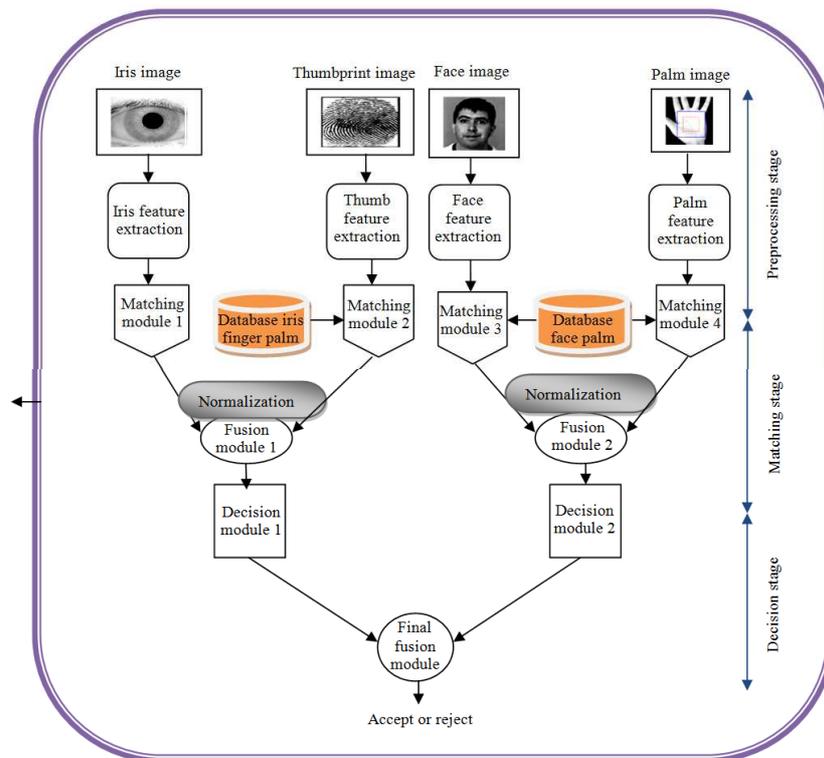

Fig. 2. A framework of the proposed score/ decision-level fusion

Conclusion

The paper reviewed most recent developments on biometric technology and their comparative pluses over conventional biometrics. Very many literatures have concluded multimodal biometric system as the best method to prevent spoof attacks, since an impostor can hardly spoof genuine user multiple biometry features simultaneously. The essay proposed integrated approach of fusion face, iris, palm and thumbprint features to form a sole recognition system, so as to highly protect users' identity in extremely restricted environments. However, to investigate the experimental contention of the approach and its influence to security reassurance, a simple but robust means of fusion algorithms is considered, so that training the user how to use the system will not be complicated. Furthermore, more statistical algorithms and classifiers will be exploited to intensively prove the benefit of this research and pronounce the most robust algorithms in the literature. Finally, we hope to see in the subsequent chapters following this research, the theoretical model of the integration to buttress the proposed method.

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Author's Contributions

Fatma Susilawati Mohamad: This author suggested the proposed concept and contributed to the analysis of the design and was aware of all the preparation of this manuscript and gave final approval of the final version to be submitted.

Ahmad Salihu Ben-Musa: This author participated in reviewing some of the related works and assisted in drafting and revising the article critically to ensure the manuscript followed good structure. He also gave final approval of all the versions to be submitted.

Zahraddeen Sufyanu: This author made substantial contributions to conception and design and in handling the revised manuscript. However, he interpreted the new idea with intellectual discussions.

Ethics

The authors strive to ensure that the work provides novelty in technical innovation and it has never been published elsewhere. The design criteria will be well assessed in future studies to avoid any risk in implementation of this approach. All authors are accountable for any revised version. Therefore, no conflict of interest declared.

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