

Multisensor Biometric Evidence Fusion for Person Authentication using Wavelet Decomposition and Monotonic-Decreasing Graph

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Abstract—This paper presents a novel biometric sensor generated evidence fusion of face and palmprint images using wavelet decomposition for personnel identity verification. The approach of biometric image fusion at sensor level refers to a process that fuses multispectral images captured at different resolutions and by different biometric sensors to acquire richer and complementary information to produce a new fused image in spatially enhanced form. When the fused image is ready for further processing, SIFT operator are then used for feature extraction and the recognition is performed by adjustable structural graph matching between a pair of fused images by searching corresponding points using recursive descent tree traversal approach. The experimental result shows the efficacy of the proposed method with 98.19% accuracy, outperforms other methods when it is compared with uni-modal face and palmprint authentication results with recognition rates 89.04% and 92.17%, respectively and when all the methods are processed in the same feature space.

Keywords-multimodal biometric fusion; sensor fusion; image fusion; face biometric; palmprint biometric; SIFT operator; wavelet decomposition; structural graph

I. INTRODUCTION

In biometric, human identity verification systems seek considerable improvement in reliability and accuracy. Several biometric authentication traits are offering ‘up-to-the-mark’ and negotiable performance in respect of recognizing and identifying users. However, none of the biometrics is giving cent percent accuracy. Multibiometric systems [1] remove some of the drawbacks of the uni-modal biometric systems by acquiring multiple sources of information together in an augmented group, which has richer detail. Utilization of these biometric systems depends on more than one physiological or behavioral characteristic for enrollment and verification/ identification. Some researchers presented multimodal biometrics [2-3] with various levels of fusion, namely, sensor level, feature level,

matching score level and decision level. Despite the abundance of research papers related to multimodal biometrics, fusion at low level / sensor level by biometric image fusion may be an emerging area for biometric authentication. But, due to proper image registration it is quite impossible to achieve fusion at low level. The available multisensor produced evidence fusion already been successfully used in many applications [4], such as biomedical informatics, remote sensing imaging, and machine vision.

A multisensor multimodal biometric system fuses information at low level or sensor level of processing is expected to produce more accurate results than the systems that integrate information at a later stages, namely, feature level, matching score level, because of the availability of more richer and relevant information.

Face and palmprint biometrics have been considered and accepted as most widely used biometric traits, although the fusion of face and palmprint is not studied at sensor level / low level when it is compared with existing multimodal biometric fusion schemes. Due to incompatible characteristics of face and palmprint images, where a face image is processed as holistic texture features on a whole face or divided the face into local regions and palmprint consists of ridges and bifurcations along with three principal lines, difficult to integrate in different levels of fusion in biometric.

This paper reports a novel approach to fuse face and palmprint images captured by multiple sensors at low level before feature extraction work. Feature extraction and auto registration are done by using scale invariant feature transform (SIFT) [6], [9], [7], [10] and after feature extraction, auxiliary feature vectors of SIFT features are constructed for gallery and probe fused images. Matching between a pair of fused images is accomplished by incorporating structural graph matching. Experimental results on IITK database are reported confirming the validity

and efficacy of the proposed approach for biometric multisensor fusion.

This paper is organized as follows. The following section introduces the process of multisensor biometric evidence fusion using wavelet decomposition. Section 3 presents an overview of feature extraction by using SIFT features. Structural graph for corresponding points searching and matching is discussed in section 4. Experimental results are discussed in section 5 and conclusion is drawn in section 6.

II. WAVELET DECOMPOSITION FOR MULTISENSOR BIOMETRIC EVIDENCE FUSION

Multisensor image fusion refers to a process that fuses images to generate a complete fused image at low level, which extracts redundant and complementary information from a set of images. The fused image should have more useful and richer information. The fusion of the two images can take place at the signal, pixel, or feature level [5].

The proposed method for evidence fusion is presented which is based on the image decomposition into multiple-channel depending on their local frequency. The wavelet transform provides a framework to decompose image into a number of new images, each of them having a different degree of resolution. According to Fourier transform, the wave representation is an intermediate representation between Fourier and spatial representations. It has the capability to provide good localization for both frequency and space domains.

The wavelet based image fusion would be applied to two-dimensional multispectral face and palmprint images at each level as shown in Figure 1.

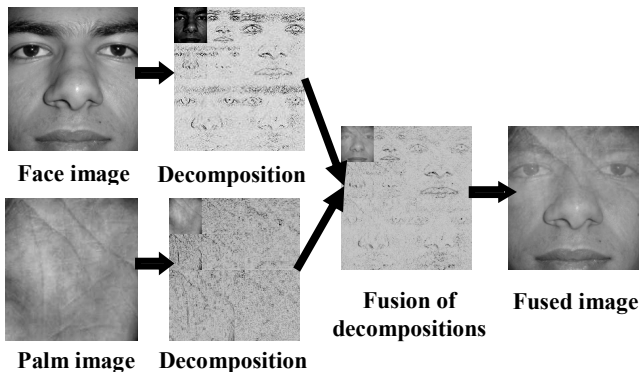


Figure 1. Wavelet based face and palmprint images decomposition and fusion of decompositions to a complete fused image.

In wavelet based image fusion [4-5], decomposition is done with a high resolution image and it decomposes an image into a set of low resolution images with wavelet coefficients for each level. Then, it replaces a low resolution image with a MS band at the same spatial resolution level and finally, performs a reverse wavelet transformation to convert the decomposed and replaced set back to the original resolution level.

III. SIFT FEATURE EXTRACTION

The scale invariant feature transform, called SIFT descriptor, has been proposed by [6], [9] and proved to be invariant to image rotation, scaling, translation, partly illumination changes. The investigation of SIFT features for biometric authentication has been explored in [7], [10]. The basic idea of the SIFT descriptor is detecting feature points efficiently through a staged filtering approach that identifies stable points in the scale-space. Local feature points are extracted through selecting the candidates for feature points by searching peaks in the scale-space from a difference of Gaussian (DoG) function. Then the feature points are localized using the measurement of their stability and assign orientations based on local image properties. Finally, the feature descriptors, which represent local shape distortions and illumination changes, are determined.

In the proposed work, first the fused image is normalized by histogram equalization and after normalization invariants SIFT features are extracted from the fused image. Each feature point is composed of four types of information – spatial location (x, y), scale (S), orientation (θ) and Keypoint descriptor (K). For the sake experiment, only keypoint descriptor [6], [9], [10] information has been taken which consists of a vector of 128 elements represent neighborhood intensity changes of current points. More formally, local image gradients are measured at the selected scale in the region around each keypoint. The measured gradients information is then transformed into a vector representation that contains a vector of 128 elements for each keypoints calculated over extracted keypoints. These keypoint descriptor vectors represent local shape distortions and illumination changes. In Figure 2, SIFT features are extracted on the fused image is shown.

Next, we shall describe a matching technique by structural graph for establishing correspondence between a pair of fused biometric images by searching a pair of point sets using recursive descent tree traversal algorithm.

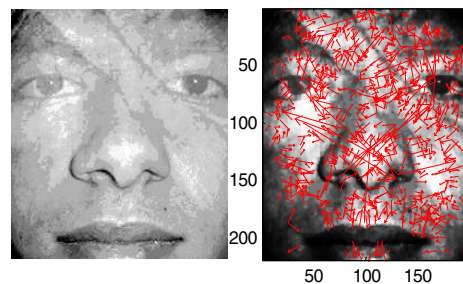


Figure 2. SIFT features are extracted from fused image. In left, fused image is shown and in right, fused image with extracted SIFT features is shown.

IV. STRUCTURAL GRAPH FOR MAKING CORRESPONDENCE AND MACHING

In order to establish a monotonic-decreasing graph based relation [8], [11] between a pair of fused images, a recursive

approach based tree traversal algorithm is used for searching the feature points on the probe/query fused sample, which are corresponding to the points on the database/gallery fused sample. Verification is performed by computing of differences between a pair of edges that are members of original graph on gallery sample and graph on probe sample, respectively.

The basic assumption is that the moving features points are rigid. Let $\{g_1, g_2, \dots, g_m\}$ and $\{p_1, p_2, \dots, p_n\}$ be two set of feature points at the two time instances and where $m = n$ or $m \neq n$ might be possible. But, in 99% cases, it has been seen that, identical set of feature points are not available from a pair of instances of a same user or from different users. So, the second case (i.e., $m \neq n$) is considered for the study.

The method is used based on the principle of invariance of distance measures under rigid body motion where deformation of objects does not occur. Using this strategy [8], maximal matching points and minimum matching error is obtained. First, we choose a set of three points, say g_1, g_2 and g_3 on a given fused gallery image which are uniquely determined. By connecting these points with each other we form a triangle $\Delta g_1 g_2 g_3$ and three distances, $d(g_1, g_2)$, $d(g_2, g_3)$ and $d(g_1, g_3)$ are computed. Now, we try to locate another set of three points, p_i, p_j and p_k on a given fused probe image that also form a triangle that would be best matching the triangle $\Delta g_1 g_2 g_3$. Best match would be possible when the edge (p_i, p_j) matches the edge (g_1, g_2) , (p_j, p_k) matches (g_2, g_3) and (p_i, p_k) matches (g_1, g_3) . This can be attained when these matches lie within a threshold \mathcal{E} . We can write,

$$\begin{cases} |d(p_i, p_j) - d(g_1, g_2)| \leq \mathcal{E}_1 \\ |d(p_j, p_k) - d(g_2, g_3)| \leq \mathcal{E}_2 \\ |d(p_i, p_k) - d(g_1, g_3)| \leq \mathcal{E}_3 \end{cases} \quad (1)$$

Equation (1) is used for making closeness between a pair of edges using edge threshold \mathcal{E} . Traversal would be possible when p_i may correspond to g_1 and p_j corresponds to g_2 or conversely, p_j to g_1 and p_i to g_2 . Traversal can be start from the first edge (p_i, p_j) and by visiting n feature points, we can generate a matching graph $P' = (p_1', p_2', p_3', \dots, p_m')$ on the fused probe image which should be a corresponding candidate graph of G . In each recursive traversal, a new candidate graph P_i' is found. At the end of the traversal algorithm, a set of candidate

graphs $P_{i=1 \dots m}' = (p_{1i}', p_{2i}', p_{3i}', \dots, p_{mi}')$ are found and all of which are having identical number of feature points.

For illustration, consider with the minimal k^{th} order error from G , the final optimal graph P'' can be found from the set of candidate graphs P_i' and we can write,

$$|P'' - G|_k \leq |P_i' - G|_k, \forall i$$

The k^{th} order error between P'' and G can be defined as

$$|P_i' - G|_k = \sum_{i=2}^m \sum_{j=1}^{\min(k, i-1)} |d(p_i', p_{i-j}') - d(g_i, g_{i-j})|, \quad (2)$$

$$\forall k, k = 1, 2, 3, \dots, m$$

The equation (2) denotes sum of all differences between a pair edges corresponding to a pair of graphs. This sum can be treated as final dissimilarity value for a pair of graphs and also for a pair of fused images. It is observed that, when k value large, the less error correspondence will be found. This is not always true as long as we have a good choice of the edge threshold ϵ . Although for the larger k , more comparison is needed. For identity verification of a person, client-specific threshold has been determined heuristically for each user, and the final dissimilarity value is then compared with client-specific threshold and decision is made.

V. EXPERIMENTAL RESULTS

The experiment of the proposed method is carried out on multimodal database prepared by the authors. The Face and palmprint databases are collected at IIT Kanpur, which consists of 750 face images and 750 palmprint images of 150 individuals. The faces of different individuals in the dataset cover wide range of poses and appearances. For the sake of experiment, cropped frontal view face has been taken which cover face portion only. For the palmprint database, cropped palm portion has been taken from each palmprint image, which contains three principal lines, ridge and bifurcations. The multisensor biometric evidence fusion method presented here is considered as a semi-sensor fusion approach with some minor adjustable corrections in terms of cropping and registration in dpi. Biometric sensors generated face and palmprint images are fused at low level by using wavelet decomposition and fusion of decompositions. After fusion of cropped face and palmprint images of size 200×220 pixels, the resolution for fused image has been set to 72 dpi. The fused image is then pre-processed by using histogram equalization. Finally, the matching is performed between a pair of fused images by structural graphs drawn on both the gallery and probe fused images using extracted SIFT keypoints.

The matching is accomplished for the proposed method and the results shows that fusion performance at the semi-sensor level / low level is found to be superior when it is compared with other two methods, namely, palmprint verification and face recognition drawn on same feature space. Multisensor biometric fusion produces 98.19%

accuracy, while face recognition and palmprint recognition systems produce 89.04% accuracy and 92.17% accuracy, respectively, as shown in the Figure 3. The ROC curves shown in Figure 3 illustrate the trade-off between accept rate and false accept rate. Further it shows that the increase in accept rate is accompanied by decrease in false accept rate happens in each modality, namely, multisensor biometric evidence fusion, palmprint matching and face matching.

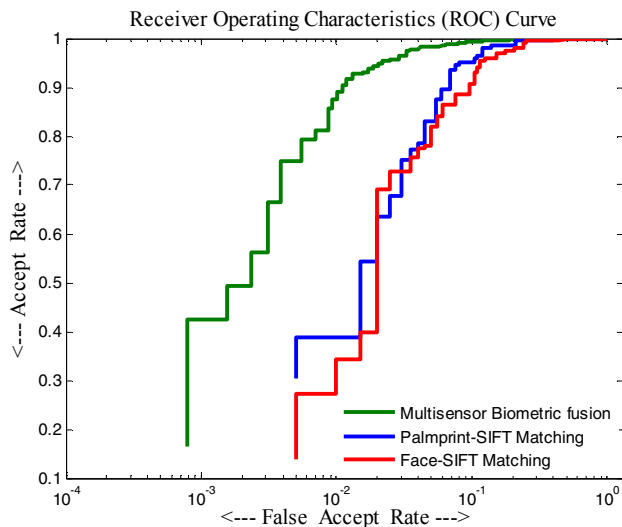


Figure 3. ROC curves (in 'stairs' form) for the different methods are shown.

VI. CONCLUSION

A novel and efficient method of multisensor biometric image fusion of face and palmprint for personal authentication is proposed. High-resolution multispectral face and palmprint images are fused using wavelet decomposition process and matching is performed by monotonic-decreasing graph drawn on invariant SIFT features. For matching, correspondence has been established by searching feature points on a pair of fused images using recursive approach based tree traversal algorithm. To verify the identity of a person, test has been done with IITK multimodal database consists of face and palmprint samples. The result shows that the proposed method initiated at the low level / semi-sensor level is robust, computationally efficient and less sensitive to unwanted noise confirming the validity and efficacy of the system, when it is compared with mono-modal biometric recognition systems.

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