

A Survey on Palmprint Recognition

Parmeshwar Manegopale

Assistant Professor, Department of Electronics & Telecommunication, Manohar Phalke Polytechnic, Sion, Mumbai, India.

Abstract: Biometric recognition refers to an automatic recognition of individuals based on a feature vector(s) derived from their physiological and/or behavioral characteristic. Palmprint recognition is one of the popular methods which has been investigated over last fifteen years due to its several advantages such as stable line features, low-resolution imaging, low-cost capturing device, and user-friendly. This paper is an attempt which provides an overview of current palmprint research, explaining in particular capture devices, preprocessing, verification algorithms, and palmprint-related fusion. Various palmprint recognition methods are compared and finally future directions are discussed.

Keywords: Biometrics, Palmprint recognition, Verification, Identification, Security

I. INTRODUCTION

Traditionally, passwords or ID cards have been used for applications, ranging from border and airport security, time and attendance control, access to restricted areas, online banking. These types of identity recognition methods present serious disadvantages, as they become less and less secure in a world where security serious disadvantages, as they become are escalating (e.g. identify theft, terrorism) [1]. The increasing need for improved and higher security system has been accompanied by a continuous research and commercial growth of biometric related technologies being expected that the global biometric market is to grow at an annual rate of more than 20% through 2012 according to a new market research report [2].

Biometrics refers to methods for uniquely recognizing humans based upon one or more physical or behavioral traits. (1) Physiological characteristics are related to the physical characteristics of the body. Examples include fingerprints, face, DNA, hand and palm geometry, iris feature, which has largely replaced retina, and odor/scent. (2) Behavioral characteristics are related to the behavior of a person. Examples include gait, and voice. Some researchers have coined the term behaviometrics for this class of biometrics.

In information technology, in particular, biometrics is used as a form of access control. Biometric technologies are becoming the foundation of highly secure identification and personal verification solutions. With an increase in level of security breaches and transaction frauds, the need for highly secure identification and personal verification technologies is becoming apparent. The major advantage of biometric system over traditional methods is that they are typically unique for each person and cannot be forged.

In biometrics there are two types of identity matching: identification and verification. *Identification* is a one-to-many comparison of an individual's biometric sample against a template database of previously gathered samples. *Verification* refers to a one-to-one comparison between a previously acquired template of an individual and a sample which we want to authenticate. An application providing verification support would also require some other means for the user to claim his identity (e.g. information contained in a smart card, keyboard for user input), while for identification purpose this is not needed.

Palmprint recognition uses the person's palm as a bio-metric for identifying or verifying person's identity. Palmprint patterns are a very reliable biometric and require minimum cooperation from the user for extraction. Palmprint is distinctive, easily captured by low resolution devices as well as contains additional features such as principal lines, wrinkles and ridges. Therefore it is suitable for everyone and it does not require any personal information of the user.

Palm normally contains three flexion creases (principal lines), secondary creases (wrinkles) and ridges. The three major flexions are genetically dependent; most of other creases are not [3]. Even identical twins have different palmprints. These non-genetically deterministic and complex patterns are very useful in personal identification. Palm is the inner surface of the hand between the wrist and fingers. Palm area contains large number of features such as

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principle lines, wrinkles, minutiae, datum point features and texture images [4]. Most of the system uses the low resolution image [5].

The palmprint image is captured using a palmprint scanner. Preprocessing has two parts, image alignment and region of interest (ROI) selection. ROI selection is the cropping of palmprint image from the hand image. Feature extraction stage obtains proposed features from the preprocessed palmprints. At the last matching compares the captured image features with the stored templates. Methods belonging to low resolution images (75 or 150dpi); where only principal lines, wrinkles, and texture are evident [6]. Various feature extraction techniques used for low resolution palmprint recognition includes: different edge detection methods to extract palm lines, Gabor filter or wavelets, then use a subspace projection like principal component analysis or linear discriminant analysis to reduce their dimensionality and adopt distance measures or classifiers to compare the reduced features. Methods belonging to the high resolution images (500dpi), where, in addition to principal lines and wrinkles, more discriminant features such as ridges, singular points and minutiae can be extracted.

A. Biometric System Characteristics:

Universality: This means that every person should have the characteristic.

Uniqueness: This measures the capacity of the biometric to distinguish a person from all the others.

Permanence: This states how well a biometric resists aging and others variations over time.

Collectability: It refers to the ease of acquisition for measurement.

Performance: This is a measure of the accuracy, speed and robustness of the technology used.

User Acceptability: is the term given to the response generated by the biometric characteristic among the subjects who are to use the technology. It basically refers to the ease of use for the subject.

Circumvention: refers to how easy it is to fool the system.

B. Performance Metrics

The recognition results of a palmprint recognition system should be reported with commonly used performance evaluation tools to simplify system comparisons. Following are the most widely used standard metrics for analyzing the accuracy and performance of a biometric system.

False acceptance rate (FAR): FAR is the ratio of the number of unauthorized (unregistered) users accepted by the biometric system to the total of identification attempts made.

False rejection rate (FRR): FRR is the ratio of the number of number of authorized users rejected by the biometric system to the total number of attempts made.

Equal-Error-Rate (EER) is defined as the rate at which the FAR is equal to the FRR.

In a top security system (e.g. an airport, bank) the FAR value must be minimum or zero, which might lead to a high FRR value. Given that a user has the possibility of making multiple access attempts, a high FRR may however not be an important problem. A very low number for ERR indicates a system with a good balance of sensitivity but is not necessarily the adequate operating point. Based on this contingency table, several performance evaluation metrics can be derived: (1) True Positive (TP) (2) True Negative (TN) (3) False Positive (FP) (4) False Negative (FN) (5) Accuracy (ACC)

Figure 1 shows various stages in palmprint recognition. This paper is organized as follows: Section 2 describes palm

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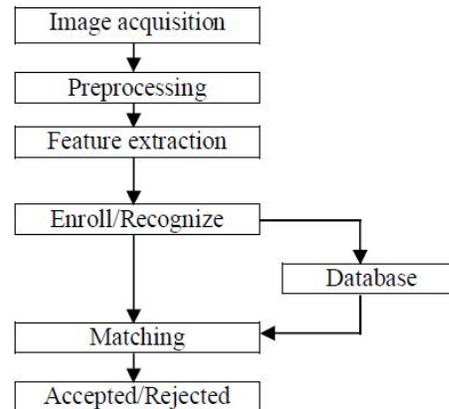


Figure 1: Palmprint recognition steps

image acquisition devices, in section 3 preprocessing methods are discussed, Section 4 explores the feature extraction and matching methods, and finally section 5 concludes the paper.

II. PALMPRINT ACQUISITION

To capture palmprint image, various types of scanner devices are used. Few of the examples are CCD-based scanners, digital scanners, video camera and tripod to collect palmprint images. A CCD-based scanner captures high resolution images and aligns palms accurately whereas, digital scanners produces low quality image and requires large time for scanning. Figure 2 shows one of the palmprint image from Hong Kong Polytechnic University captured using CCD. Digital scanners are cost-effective to collect palmprint images. However, they cannot support real-time verification because of the scanning time. Digital cameras and video cameras are two ways to collect contactless palmprint images. Digital scanners are not suitable for real-time applications because of the scanning time. Also the quality of digital camera is low because they collect is in an uncontrolled environment with illumination variations and distortions due to hand movement.



Figure 2: A CCD-based palmprint scanner

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III. PREPROCESSING

Preprocessing is used to align different palmprint images and to segment the center for feature extraction. Most of the preprocessing algorithms employ the key points between fingers to set up a coordinate system. Preprocessing involves five common steps: (1) binarizing the palm images, (2) extracting the contour of hand and/or fingers, (3) detecting the key points, (4) establishing a coordination system and (5) extracting the central parts.

Figure 3(a) shows the key points whereas (b) shows a preprocessed image. The first and second steps in all the preprocessing algorithms are similar. However, the third step has several different implementations including tangent, bisector and finger-based to detect the key points between fingers. The tangent-based approach considers the two boundaries—one from point finger and middle finger and the other from ring finger and last finger—as two convex curves and computes the tangent of these two curves. The two intersections are considered as two key points for establishing the coordinate system. Tangent-based approaches have several advantages [7]. It is robust to incomplete and the presence of rings.

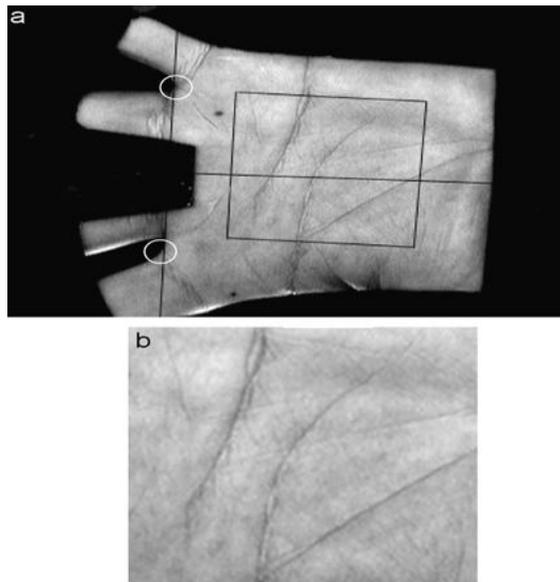


Figure 3: (a) key points and coordinate system, (b) ROI extraction

Bisector-based approach constructs a line using two points, the center of gravity of a finger boundary and the midpoint of its start and end points. The intersection of the line and the finger boundary is considered a key point. The multiple finger approach uses a wavelet and a set of predefined boundary points on the three fingers to construct three lines in the middle of the three fingers. The two lines from point and ring fingers are used to set the orientation of the coordinate system and the line from the middle finger is used to set its position. After obtaining the coordinate systems, the central parts of palmprints are segmented. Most of the preprocessing algorithms segment square regions for feature extraction but some of them segment circular and half elliptical regions. The square region is easier for handling translation variation, while the circular and half elliptical regions may be easier for handling rotation variation.

IV. FEATURE EXTRACTION AND MATCHING

The aim of this section is to recognize a correct person to authenticate and to prevent multiple people from using the same identity. Once the central part is obtained, features are extracted for recognition. These features are used to create a standard template which is stored in the system database. While in Feature matching a matching score is obtained by matching the identification template against the standard templates. If the score is less than a given threshold, the user is authenticated. Many features of a palmprint can be used to uniquely identify a person. Various algorithms have been developed to be used in palmprint recognition. Developed algorithms mainly include different methods for feature extraction and distance matching. Mainly, all the palmprint algorithms are broadly classified as: (1) Line-Based

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Approaches (2) Subspace-based approaches and (3) Statistical approaches. Algorithms based on all these three approaches are explained below.

With increasing interest in low resolution palmprint recognition, researchers have proposed a variety of palmprint feature extraction and verification approaches in which palmprint images can be represented either in a spatial or a transform domain. An algorithm to extract contour of palmprint based on corner point features is proposed in [8]. Firstly, a lot of excircles were made along the edges of palmprint; Secondly the approximate corner point positions of palmprint are located by calculating the intersection number of palmprint edges and the excircles; Finally, ROI region are extracted by the means of inscribed circle of square, then extract and match the texture feature by combining with palmprint features and relative knowledge. The recognition rate noted was 98.6%.

A frequency domain feature extraction algorithm for palm-print recognition is proposed in [9], which efficiently exploits the local spatial variations in a palmprint image. The entire image is segmented into several narrow-width spatial bands and a palm-print recognition scheme is developed based on extracting dominant spectral features from each of these bands using two-dimensional discrete cosine transform (2D-DCT). The proposed dominant spectral feature selection algorithm offers an advantage of very low feature dimension and it is capable of capturing precisely the detail variations within the palm-print image, which results in a very high within-class compactness and between-class separability of the extracted features. A high-resolution palmprint recognition system based on minutiae is introduced in [10]. Each step has been specifically designed and optimized to process large palmprint images with a good tradeoff between accuracy and speed. A sequence of robust feature extraction steps allows to reliably detect minutiae; moreover, the matching algorithm is very efficient and robust to skin distortion, being based on a local matching strategy and an efficient and compact representation of the minutiae. Experimental results show that the proposed system has ERR <0.01%.

A real time personal identification based on Fourier transform for palm-print recognition is proposed in [11]. An auto hand gesture segmentation method is proposed first and after the segmentation, a modified Fourier transform are used for the image processing. Machine leaning based trainings are used to get the palm print training database. A spectral feature extraction algorithm is proposed for palm-print recognition, which can efficiently capture the detail spatial variations in a palm-print image in [12]. The entire image is segmented into several narrow-width bands and the task of feature extraction is carried out in each band using two dimensional Fourier transform. It was shown that the proposed dominant spectral feature selection algorithm is capable of capturing the variation. within the palmmage, but also a very high within-class compactness and and betweenclass separability. The various details associated with Palm Print Recognition is analyzed and devised an algorithm to do so that works with Discrete Wavelet Transforms in [13]. The Wavelets used are those of the D.C.T., Eigen, Haar, Hartley, Walsh, Slant Transforms. Further Results are presented by incorporating wavelets of the lesser-used Helmert and Kekre Transforms. It is seen that all these Wavelets give us accuracies close to 93% with the database of over 8000 images.

A multi-resolution feature extraction algorithm for palm-print recognition is proposed based on two-dimensional discrete wavelet transform (2D-DWT), which efficiently exploits the local spatial variations in a palmprint Image in [14]. The entire image is segmented into several small spatial modules and the effect of modularization in terms of the entropy content of the palm-print images has been investigated. A palm-print recognition scheme is developed based on extracting dominant wavelet features from each of these local modules. In the selection of the dominant features, a threshold criterion is proposed, which not only drastically reduces the feature dimension but also captures precisely the detail variations within the palm-print image. A principal component analysis is performed to further reduce the feature dimensions. A technique is proposed called 'Advanced palmprint recognition using unsharp masking and histogram equalization [15]. The system makes palmprint recognition simpler and more accurate. Unsharp masking is for sharpening the edges while histogram equalization is used to improve the contrast of images. Proposed system with its user friendly environment and high security lets the users to depend more on their security needs.

An automated scanner-based palmprint recognition system is proposed in [16]. The system automatically captures and aligns the palmprint images for further processing. Several linear subspace projection techniques have been tested and compared like principal component analysis (PCA), fisher discriminant analysis (FDA) and independent component analysis (ICA). In order to analyze the palmprint images in multi-resolution-multifrequency representation, wavelet transformation is also adopted. The images are decomposed into different frequency subbands and the best performing subband is selected for further processing. Experimental result shows that application of FDA on wavelet subband is able to yield both FAR and FRR as low as 1.356 and 1.492% using our palmprint database.

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Extraction of region of interest (ROI) from a palmprint considerably improves the efficiency of identification systems as ROI extracted palmprint images have more entropy and require less processing and storage [17]. In the proposed method, authors extracted the ROI of palmprints of two sets of databases, Hongkong Polytechnic University low resolution palmprint Database and high resolution indigenous database. In one of the approach, a palmprint image is first decomposed into multiple subbands by using DT-CWT [18]. After that, each subband in complex wavelet domain is divided into non-overlapping sub-regions. Then Local Binary Pattern Histogram (LBPHs) are extracted from each sub-region in each subband, and lastly, all of LBPHs are weighted and concatenated into a single feature histogram to effectively represent the palmprint image. A Chi square distance is used to measure the similarity of different feature histograms and the final recognition is performed by the nearest neighbourhood classifier. A group of optimal parameters is chosen by 20 verification tests on palmprint database.

An enhanced Gabor-based region covariance matrices (EGRCM) method for palmprint recognition is proposed in [19]. The Gabor magnitude (GM) and the Gabor phase (GP) of a certain image contain effective information for image feature extraction, they are utilised simultaneously to construct the proposed EGRCM image descriptor for palmprint recognition. Experimental results demonstrate the recognition accuracy of 91% using the proposed method.

A method is proposed in which the features consist of primary lines and secondary lines and their intersections [20]. The primary lines are fitted with polynomial equations whose coefficients are utilized in the new entropy function. A fuzzy rule is constructed in which the entropy function make their way into the criterion function for the purpose of learning parameters which modify the coefficients of all the primary lines. While learning the parameters, the reinforcement learning law leads to the fast convergence of the parameters. A novel Gabor-based kernel principal component analysis (PCA) method by integrating the Gabor wavelet representation of palm images and the kernel PCA method for palmprint recognition is proposed in [21]. In the proposed method, Gabor wavelets first derive desirable palm features characterised by spatial frequency, spatial locality, and orientation selectivity to cope with the variations of illumination. The kernel PCA method is then applied to project palmprints from the high-dimensional palmprint space to a significantly lower-dimensional feature space, in which the palmprints from the different palms can be discriminated much more efficiently. Subspace learning methods are very sensitive to the illumination, translation, and rotation variances in image recognition [22]. A method is proposed using a new descriptor of palmprint named histogram of oriented lines (HOL), which is a variant of histogram of oriented gradients (HOG). HOL is not very sensitive to changes of illumination, and has the robustness against small transformations because slight translations and rotations make small histogram value changes.

The influence of the inside-lobe size for the Modified Phase-Only Correlation (MPOC) technique in Partial Palmprint Rotation Invariant and DEgraded Recognition (PP-RIDER) is analyzed in [23]. In fact, MPOC may produce spurious peaks around the main correlation peak which, when using too small inside-lobe sizes, can affect negatively the similarity scores in genuine comparisons.

A new approach is presented for person identification by extracting the features of multispectral palmprint images in region of interest after preprocessing of multispectral palmprint images [24]. Here 2D-gabor filter is used since it is an effective tool for texture analysis and more robust to brightness for feature extraction. The extracted feature is fused at score level and image level. Finally, the Euclidean distance is used for matching of palmprint features in the database. To improve the performance and the robustness of the system, multispectral palmprint images were employed to acquire more discriminative information in [25]. Authors introduced a novel multispectral recognition method using the fusion of palmprint and palm vein features to increase the accuracy of the biometric person recognition using K nearest neighbor (KNN), Support Vector Machine (SVM) and 'One-Against-One' multiclass SVM (OAO-SVM) with RBF kernel using 6-folders crossvalidation to assess the generalization capability of the proposed biometric system. . The proposed approach is based on statistical study and energy distribution analysis of Finite Ridgelet transform coefficients, involving so low computation complexity.

A novel method is proposed for a palmprint recognition based on multifractal spectrum technology using statistical moment approaches. The multifractal spectrum of palmprint is calculated by developing an algorithm for extracting palmprint characteristics [26]. The three parameters proposed as the distinguishing palmprint features include the width spread and maximum of multifractal spectrum, and a parameter which describes the asymmetry of the spectrum curve. The identification process is divided into five main steps.

The spectral minutiae representation has been proposed as a novel method to minutiae-based fingerprint recognition, which can handle minutiae translation and rotation and improve matching speed in [27]. A spectral

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minutiae representation to palmprints is applied and implement spectral minutiae based matching. Experimental results show that EER 15.89% and 14.2% are achieved on the public highresolution palmprint database THUPALMLAB using location-based spectral minutiae representation (SML) and the complex spectral minutiae representation (SMC) respectively while 5.1% and 3.05% on FVC2002 DB2A fingerprint database. Orientation feature has been demonstrated to be one of the most effective features for low resolution palmprint recognition [28]. Using steerable filter, Authors investigated the accurate orientation extraction and appropriate distance measure problems for effective palmprint recognition. First, high order steerable filter to extract accurate continuous orientation are used and quantified it into discrete representation. Then, for effective matching of accurate orientations, a generalized orientation distance measure is proposed.

A method is proposed for palmprint identification using Transform Domain and Spatial Domain Techniques (PITS) in [29]. Histogram equalization is used on palmprint to enhance contrast of an image. The DWT is applied on Histogram equalized image to generate LL, LH, HL and HH bands. The LL band is converted into DCT coefficients using DCT. QPCA is applied on DCT coefficients to generate features. The test and database palmprint features are compared using Euclidean Distance (ED). The palmprint recognition based on Dempster-Shafer classifier combination is presented in [30]. Linear Discriminant Classifier (LDC), One Against All Support Vector Machine (OAASVM) classifier, K-Nearest Near (KNN) classifier and Dempster-Shafer classifier combination are compared by authors. From the experiment result it was concluded that DS combination approach get a better performance than those individual classifiers. A novel approach is proposed to palmprint recognition based on local Haralick features in [31]. These features are calculated from the grey-level co-occurrence matrices created on the $d \times d$ pixels subimages of the $D \times D$ pixels palmprint region. In order to identify a person, the matching process between the live template and the templates from the system database is performed in N matching modules. Fusion at the matching-score level is used and the final decision is made on the basis of the maximum of the total similarity measure.

A method is explored for a 3-D palmprint recognition by exploiting the 3-D structural information of the palm surface in [32]. The structured light imaging is used to acquire the 3-D palmprint data, from which several types of unique features, including mean curvature image, Gaussian curvature image, and surface type, are extracted. A fast feature matching and score-level fusion strategy are proposed for palmprint matching and classification. Although its recognition rate is a little lower than 2-D palmprint recognition, 3-D palmprint recognition has higher anticounterfeiting capability and is more robust to illumination variations and serious scrabbling in the palm surface. Based on the dual-tree complex wavelet transform (DT-CWT) and compressed sensing (CS), a novel and high palmprint recognition performance algorithm is proposed [33]. Firstly, DT-CWT, which provide both approximate shift invariance and good directional selectivity, is employed to represent the palmprint image with better preserving the discriminable features with less redundant and computationally efficient. Then the PCA (Principal Component Analysis), based on linearly projecting the image subband coefficients space to a low dimensional feature subspace, is employed to extract the feature of the palmprint images.

A palmprint recognition method based on eigenspace technology is presented in [34]. By means of the Karhunen–Loeve transform, the original palmprint images are transformed into a small set of feature space, called “eigenpalms”, which are the eigenvectors of the training set and can represent the principle components of the palmprints quite well. Then, the eigenpalm features are extracted by projecting a new palmprint image into the subspace spanned by the “eigenpalms”, and applied to palmprint recognition with a Euclidean distance classifier.

A novel contactless Palmprint recognition system using palm print principal line-based feature extraction technique has been proposed in [35]. The discriminative Palmprint features were extracted from a pre-processed acquired images using easily available and low cost camera. Distances from endpoints to endpoints and point of interception to endpoints were calculated and transformed to frequency domain by the application of Discrete Fourier Transformed (DFT) technique. The extracted K-points DFT coefficients has been used as the discriminating features for recognition and identification purposes using correlation technique, power spectral matching and Euclidean distance measure.

An efficient palmprint based human recognition system is presented in [36]. Each palmprint is divided into several square overlapping blocks. Reconstruction error using principle component analysis (PCA) is used to classify these blocks into either a good block or a non-palmprint block. Features from each good block of a palmprint are obtained by binarising the phase-difference of vertical and horizontal phase. The Hamming distance is used to compute the matching score between the features of corresponding good blocks of enrolled and live palmprint. These matching

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scores are fused using weighted sum rule, where weights are based on the average discriminating level of a block relative to other blocks.

A personal recognition system based on the Gabor features of colour palmprint images is described in [37]. The features are extracted by a bank of Gabor filters from the palmprint region represented by three primary spectral components R, G and B. The system, based on fusion at the matching-score level, is used to improve the recognition accuracy.

Table 1: Comparison of various palmprint recognition algorithms

Method	Feature	Classifier	Accuracy (%)
Gabor	Phase information	Hamming Distance	97.59
Log Gabor	Feature vector	PNN	92.5
PCA	Eigen palm	L1	92.4
Sobel	Line feature	Hamming Distance	94.84
ICA	Texture feature	Lcos	95.7
DFT	Statistic feature	Hamming Distance	95.48
DCT	Spectral features	Distance based	99.97
FDA	Fisher palm	L1	95.2
Contour Transform	Feature vectors	Ada-Boost	97.3
Wavelet Transform	Wavelet energy	Neural network	98

To improve the palmprint verification accuracy, an efficient palmprint alignment refinement method is proposed in [38]. After extracting the principal lines from the palmprint image, the iterative closest point method is applied to them to estimate the translation and rotation parameters between two images. The estimated parameters are then used to refine the alignment of palmprint feature maps for a more accurate palmprint matching. A novel technique to extract palm-print features based on instantaneous-phase difference obtained using Stockwell transform of overlapping circular-strips is proposed in [39]. A procedure is proposed to classify hand images into either right or left hand based on their inherent characteristics and then the palm-print region from the hand image is extracted accordingly. This palm-print region is found to be robust to translation and rotation on the scanner. The system performs with 100% correct recognition rate (CRR) and equal error rate (EER) less than 1% for all the databases. Table I shows comparison of various palmprint recognition algorithms.

A. Fusion in Biometrics

Unlike biometric systems utilizing a single biometric characteristic (unimodal systems), multimodal biometric systems combine multiple characteristics in order to improve the system performance and make the system more reliable to spoofing attacks. A multimodal biometric system requires an integration scheme to fuse the information obtained from the individual modalities. The fusion can be performed at the four different levels:

- (1) at the sensor level
- (2) at the feature-extraction level
- (3) at the matching-score level
- (4) at the decision level

V. CONCLUSION

In this paper Palmprint recognition algorithms are reviewed. Palmprint recognition has considerable potential as a personal identification technique as it shares most of the discriminative features with fingerprints and in addition possesses a much larger skin area and other discriminative features such as principal lines, ridges and wrinkles which are very useful in biometric security. Coding based techniques have proven to be efficient in terms of memory requirement and matching speed. Fusion technique is recent area in which researchers used to fuse features like appearance-based, line and texture features from palm-prints, which has led to an increase in accuracy. Recent work involves use of multiscale, multi-resolution based techniques like wavelets and contourlets are for efficient implementation of palm print recognition.

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BIOGRAPHY



Parmeshwar Manegopale is working as Assistant Professor in the department of Electronics & Telecommunication at Manohar Phalke Polytechnic, Sion, Mumbai, India. He obtained B.E. (Electronics) from Dr. BAM University, Aurangabad, Maharashtra in 1997 and M. E. (Elect. & Telecom) from Mumbai University, Mumbai, India in 2009. He has been in teaching for the past 14 years. He is life member of ISTE and IETE. He has published papers in international journals. His area of research includes Image and Speech Processing.