A Review on Palmprint Authentication System using various Feature Extraction and Classification Techniques

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***Abstract*- Biometric as a technology was largely limited to organisational and governmental purposes only where the purpose of usage was to Identify or to verify an user or individual in particular. The introduction of biometric authentication in regular consumer electronics such as smart phones has extrapolated the technology usage in numbers. In the recent years, the area of biometric has gained more popularity and as a result, become more attractive to many researchers. According to a recent study by Juniper Research, it is estimated that more than 770 million biometric authentication applications will get downloaded each year, by the year 2019. With an increase in number of users adopting biometric technology, the threat of data loss in the form of identity theft and its subsequent consequences (which may or may not be severe in nature) is significantly high and therefore a need of enhancement and upgradation of the technology becomes necessary.**

This survey paper is a resultant of an effort focussed on understanding the research developments in the area of Identification of individuals based on their palm print characteristics. Palmprint recognition is one of the major techniques which have been considered for identification and verification purpose. Image processing plays a critical function in the palm print based biometric recognition system. This system mainly operates in some common stages such as scanning of palm, pre-processing, feature extraction and finally matching of the palm within a database. There are several algorithms that have been investigated for each stage. This paper makes an attempt to review the research done on various recent and advanced palmprint recognitions systems and their comparative analysis based on the techniques used, and their respective benefits and drawbacks. Finally, some potential directions for the future are also discussed.

Keywords: Biometric recognition system, security, authentication, Palmprint recognition.

1. INTRODUCTION

A pattern recognition system is used for identification or verification of users, based on their unique physiological properties (Biggio et al., 2014). Biometric systems in general comes with various types of benefits when compared to the conventional authentication techniques such as ID card systems (Jain et al., 2011), Password, RFID enabled access control and so on. In conventional identification or verification systems mentioned above, an electronic password or a chip based RFID validation have been allocated for users to recognize them uniquely. These techniques are contained in various applications like border security, time or attendance control, online web applications, airport security, online banking, security of restricted areas, etc. However, these different varieties of recognition techniques have some disadvantages. The passwords or ID cards for example are not completely secure for all applications which are modified by strangers. The password or RFID on the other hand can easily be shared/exchanged between individuals and there will be no clarity if the concerned was physically present whilst entering the password. Situations such as this prompted researchers to work extensively on identifying physical properties of human beings that can be easily presented when needed. This initiated the need for enhanced and high-security techniques in recognitions or authentication systems, and it has been resulting in biometric related systems (Chiou et al., 2013).

In recent times, biometrics has been extensively used to validate access control in most of the cases whilst identifying the authenticity of the individual identity. As a result, Biometric systems is being extensively utilised as the basis for building identification and individual verification solutions (Wayman et al., 2005). Sighting an upswing in the number of cases regarding security violations and transactional frauds, an urgent need for a greatly dependent, stable and secure identification and verification system is clearly emanating as a core necessity than just a need. The primary benefit of having a biometric system compared to the conventional techniques is the fact that the biometric data is captured is always unique for each individual that cannot be tampered with (Bhattacharyya et al., 2009). Compared to other advanced technologies, the function of biometric applications are better to safeguard the identity of citizens. Biometrics is used as recognition systems that can identify or validate a known person or as a verification system that authenticates an individual by comparing one exact pattern stored in the database.

Nedjah et al., (2017) in their research, proposed a robust and secured biometric system by using the smart cards. From a long time, finger prints and then palm-prints have been used extensively as an identifier mechanism for humans. This biometric system therefore has always been considered as one of the most reliable mechanism to distinguish one person from another as the pattern is unique to each and every

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individual and yet very stable over time. For this implementation, the matching is completed on the card. Therefore, the biometric characteristics are always secured in the owner's card, guaranteeing the maximum safety and privacy.

In general, all the recognition techniques in biometric systems are classified into three types, namely physiological, behavioural, and chemical (Beritelli et al., 2016). In this, physiological biometric systems include Fingerprint recognition, Palmprint recognition, Facial expression recognition, Iris recognition and Hand geometry recognition. The behavioural biometric systems include Signature, Voice and Keystrokes recognition. Chemical biometrics is still in a nascent stage (Choudhary, 2012) and involves the measuring of chemical cues such as the order and the chemical composition of the human perspiration. Among these, physiological biometric systems are found to be more reliable due to its use of inherent features (Murakami et al., 2002). Seven factors that involve on a physiological characteristic received as a biometric feature are universality, uniqueness, circumvention, acceptability, permanence, collectability and performance (Ross et al., 2006). In biometrics, identification and verification are the two types of identity matching techniques that are established. Identification is the process where a one-to many relationship is attained of an individual's biometric model against a collective pattern of gathered samples. Authentication/verification as the term suggests, is with reference to a one-to-one comparison of a previously obtained template of a person with a sample with the desire to authenticate.

Among the various types of biometric techniques, palmprint recognition is one of the most trustworthy techniques (Afsal et al., 2016). Palmprints have several advantages compared to other hand-based biometric technologies such as fingerprints and hand geometry. Counterfeiting or forging a palmprint is very complex compared to a fingerprint as the palmprint texture has more data points to consider and is therefore more complicated to meddle with. The inner surface of the hand between the wrist and the fingers is generally referred to as palm which includes three flexion creases (principal lines), wrinkles, ridges, minutia points and singular points. Palmprint is unique, easily captured by low resolution apparatus and includes additional features such as principal lines, wrinkles and ridges (Nezhadian et al., 2017).

Palmprint is easy to use and more precise when compared to most of the other available options. The three major principal lines on the palm are genetically dependent; most of other lines are not dependent (Gupta et al., 2016). It is really astonishing to know that even in the cases identical twins their palmprints are found to be different. This kind of non-genetically deterministic and difficult patterns can be very critical in personal identification processes. Fig.1 shows the line patterns on the palmprint image.

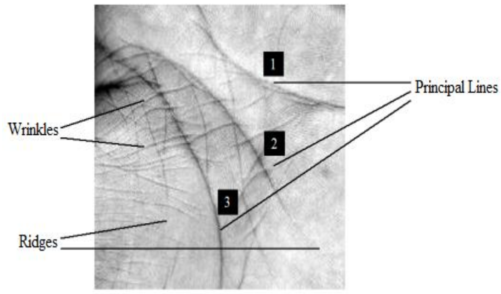

Fig.1 The Line Patterns on the Palmprint image (Michael et al., 2011).

2. PALMPRINT RECOGNITION SYSTEM

Normally a palmprint recognition system can be grouped as below: palmprint scanner, pre-processing, feature extraction and matcher. Fig.2 show that the general block diagram of Palmprint Recognition system Palmprint images can be collected using the scanner (Kaushik et al., 2016). Pre-processing is a placement of coordinate system to adjust the palmprint images and to separate a division of the palmprint for feature extraction. Feature extraction is to implement proficient features from the pre-processed palmprints. Finally, a classifier or matcher calculates the two features of palmprint.

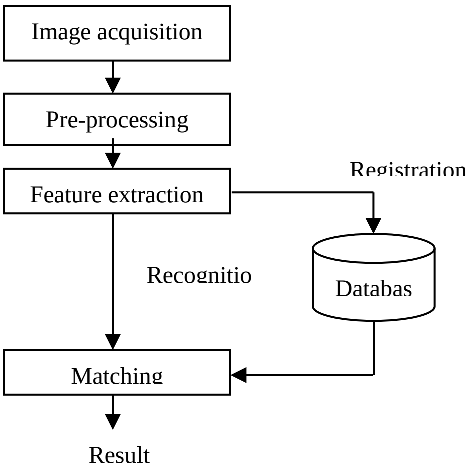

Fig. 2: General block diagram of Palmprint Recognition system.

2.1 *IMAGE ACQUISITION*

In an image acquisition process, the image of the palmprint is captured with the support of various types of different sensors. Researchers use four types of sensors such as CCD-based palmprint scanners, digital cameras, video cameras and digital scanners to collect palmprint images. CCD-based palmprint scanners confine high-quality palmprint images and place palms accurately as the scanners have pegs for guiding the position of hands (Dai et al., 2010).

2.2 *PRE-PROCESSING*

After capturing the image of the palmprint, the pre-processing is required to decrease the overheads, instead of directly using the palm-print images, (Anitha et al., 2015). Pre-processing is used to eliminate the distortion of the image, aligning of the palm-prints so as to crop the region of interest (ROI). This cropped ROI image is used for feature extraction stages.

This is prepared by using the following five stages,

1. Binarizing the palm image
2. Boundary tracking
3. Key points detection
4. Establishing a coordination system
5. Extracting the central part.

The third step is implemented by two techniques namely tangent based and finger based technique. The tangent based technique is preferred since it has more advantages. This technique considers the edges of the two finger holes on the binary image to be traced. The general tangent of the two finger holes is assumed to be the axis. The key points for the coordination system are estimated as the midpoint of the two tangent points. A low-pass filter is used on the resized image to remove the noise and smoothen the areas with slight variance while protecting the edges (EI-Seddekl et al., 2015).

2.3 Feature extraction and Matching

Feature extraction is a process that follows pre-processing and plays an essential role in image identification and verification. The objective of this stage is to extract variables that explain, unequivocally, the forms belonging to the similar class while differentiating them from the other classes. In other words, it is the process in which phase features of palm are extracted such as principal lines, texture, minutiae, density map, singular points, etc. Research on feature extraction includes transform domain, principal component analysis, texture features and hybrid feature extraction.

For identification purpose, verification approaches are used which is being categorized into line-based methods, sub-space based methods and statistic-based methods. The matching algorithm includes Euclidean distance, K-Nearest Neighbour (KNN) classifier, Support Vector Machine (SVM) and threshold based techniques.

a. Transform domain features

An extraction scheme of frequency domain feature for palm-print recognition got proposed in (Imtiaz et al., 2010), which effectively increases the local spatial deviations within a palm-print. The whole image is further segmented into some spatial bands of a narrow width and an approach for the palm-print recognition is finally implemented based on the extracting of the dominant spectral features from each of the spatial bands by using the two-dimensional discrete cosine transform.

El-Seddek et al., 2015 has presented an improved segmentation method that is square-based for palm-print alignment and extraction. Moore's algorithm has been used to obtain the hand contour effectively without any holes being visible. A set of reference points are obtained using the curvature scale space corner detector with an adaptive threshold and dynamic region of carry to high accuracy to detect a ROI.

A palm-print recognition is done using a spectral feature extraction algorithm, which is effectively capturing the detail spatial deviations from within a palm-print image (Imtiaz et al., 2010). Several narrow-width bands are retrieved from the image and the feature extraction task is processed in each band using the two dimensional Fourier transforms. It was also shown that variation can be captured using the proposed dominant spectral feature extraction procedure.

A discrete wavelet transform based palm-print recognition using a multi-resolution feature extraction technique is presented in a way that effectively develops the local spatial deviations in a palmprint Image in (Imtiaz et al., 2013). The entire image is divided into several small spatial segments and the result of modularization based on the entropy substance of the palm-print images has been implemented. Misar & Gharpure, (2015) proposed a method where the feature coefficients obtained from the Discrete Wavelet Transform (DWT) to generate the feature vector. The results are obtained from feature matching or classification techniques using Neural Network have been discussed.

Shashikala et al., 2012, proposes a technique using Transform Domain and Spatial Domain Techniques (PITS) for palm-print identification. The contrast of an image is improved using histogram equalization. DCT coefficients are retrieved from the LL band using Discrete Cosine Transform. Features are produced by applying QPCA on DCT coefficients. The analysis and training database palmprint features are compared using Euclidean Distance based matching algorithm.

Sanyal et al., (2015) proposed a new palm-print based biometric authentication system. The histogram of the palm-image is cross wavelet transformed (XWT) with respect to that of a reference palm image. Bacterial Foraging Optimization Algorithm (BFOA) is used to select the combination of features that results in the best performance. An approach high palmprint recognition performance algorithm based on the dual tree complex wavelet transforms (DT-CWT) and compressed sensing (CS) is proposed (Li et al., 2012).

b. Principal Component Analysis

A new Gabor-based kernel principal component analysis (PCA) approach by combining the Gabor wavelet representation of palm images and the kernel PCA technique for palmprint recognition is proposed (Ekinci et al., 2007). Palm-prints are projected from the high-dimensional palmprint space to a considerably lower-dimensional feature space by applying the kernel PCA method, where the palm-prints from the various other palms can be discriminated much more effectively and efficiently.

A two steps centre of mass moment method for ROI selection of palmprint with PCA and hausdroff distance method is proposed (Vivekanandam et al., 2012). The experimental results are obtained with accuracy as high as 98.781%. Also, the result shows that the performance of the system is relatively stable and the database size is increased. Furthermore, the results show the best identification among the various compared methods without satisfying the verification accuracy.

c. Texture Features

A detail research for palm print identification that aims to get high recognition accuracy is proposed (Harb et al., 2015). In this, feature extraction is done using line based methods such as Gabor, Canny filters and Modified Finite Radon Transform to represent palm lines. Radon coefficients are used as input features vector, two classification techniques are used namely matching by correlation and Support Vector Machines.

The features of multispectral palmprint images in region of interest are extracted after pre-processing of multispectral palmprint images for person identification (Valarmathy et al., 2012). The 2D-Gabor filter is further used as it is considered to be an effective tool for the purpose of texture analysis as it is more robust. The extracted feature is further merged at the score level and the image level. At last, the palmprint features are matched using Euclidean distance.

A new method is proposed to palmprint recognition based on local Haralick features (Ribaric et al., 2012). The features are estimated from the (GLCM) grey-level co-occurrence matrices created on the d x d pixels sub-images of the D x D pixels palmprint region. The matching procedure between the live template and the templates from the scheme database is performed in N matching methods in order to identify a person,. The decision is made on the basis of the maximum of the total similarity measure by using the fusion at the score level.

Features are further extracted using a bank of Gabor filters from the palmprint region denoted by R, G and B, the three primary spectral components. A scheme, based on the fusion at the matching-score level, is developed to improve the accuracy of recognition. Latha & Prasad, (2017) proposed an intra-modal authentication system that was based on the texture information extracted from the palmprint using the Haralick features, 2D-log Gabor filters, 2D-Gabor. An individual feature vector is estimated for a palmprint using the extracted texture information of each filter method.

Bounneche et al., 2016 has proposed a multi-spectral palm-print recognition method that was based on the oriented multi-scale log-Gabor filters and bitwise competitive coding. They also presented a new matching process which applies the bitwise Hamming distance and KL divergence allowing them to capture the similarities between palmprint feature maps generated using 2D log-Gabor filters with bitwise competitive code efficiently.

Another area of interest in the texture based biometric technology is the comparison between the 2D and 3D image capturing. Wei Li et al., (2009) in one of the research paper has clearly focussed on the fact that in-spite of the human palm surface being three dimensional, less effort has been contributed towards developing the 3D image capturing and processing where the depth of the palmprint could be exploited. Although 2D palmprint recognition can attain higher accuracy rates, counterfeiting a 2D palmprint is considerably easy. It is therefore about time that more and more effort should be put towards identifying technologies / methodologies / techniques that are more efficient and fool proof and 3D palmprint recognition could possibly be one of the answers. Zang et al., 2010 in their research for more accuracy tried combining both 2D and 3D palmprint recognition concluded that the new system they proposed was more robust.

d. Hybrid Features

A personal recognition system is proposed (Jaswal et al., 2015), which based on the central part of hand. The System makes use of 2D-Gabor filter for feature extraction and then apply Principle Component Analysis (PCA) along with LDA for dimensionality reduction process. Finally, system applies Euclidean distance on a reduced set of palm print features for their classification. The performance of the system is tested on IITD and CASIA databases and proves that system achieves 91% of accuracy with high true recognition rate and computation time.

A novel approach is proposed (Younesi et al., 2017) for personal identification based on palmprint. Initially, ROI of obtained palmprint is extracted and then was given to Gabor filter bank includes four filters.

Varshney et al., 2014 has proposed a Hybrid (DWT-DCT) Transform for palm-print recognition and performance comparison that is prepared with DWT and DCT transforms. In a Hybrid DCT-DWT domain, initially the DWT is applied on an image and then segmented on the approximated coefficients (LL) and then, the DCT coefficients and the formation of feature vector is found to be same as in DCT domain after applying the DCT on each approximation band.

A hybrid technique by using combination of 2D-LPF, PCA and Gabor filter approaches are proposed (Kaushik et al., 2016). In this proposed approach, it was found that they offer a better accuracy with minimum complexity in the recognition of the palm-print. Also, they have introduced a method that significantly reduces the issue of PCA based palmprint recognition system. It is recommended that is necessary to first pre-process the palm-print database as the central part of palm is discriminatory for different person as per this proposed technique.

Meraoumia et al., 2015 has proposed a multimodal biometric personal identification system that was based on the features extracted from the palm-print images. In this proposed model, HOG descriptors are used for the feature extraction processes. Three different classifiers from each of the palm-print modality were used for the purpose. The classifiers were trained with the HOG features from all the palm-print images.

A verification algorithm based texture feature is also proposed (Nezhadianet al., 2017). A new method of Gabor filters based GLCM and DWT technique is used for extraction of the texture features. Also, K-Nearest Neighbour

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(KNN) Classifier is used for classification of extracted feature. Using this verifier, the technique obtains 98.75% accuracy with 60% train and the method has less ERR.

3. PERFORMANCE METRICS

A biometric recognition system is developed in two different modes namely identification and verification. Identification is the method of trying to determine out a user's identity by investigating a biometric pattern estimated from the user's biometric features. Hence, the performance of biometric system is evaluated using three parameters such as False Rejection Rate (FRR), False Acceptance Rate (FAR) and Equal Error Rate (EER) (Ali et al., 2016). The main objective of the biometric system is to achieve low values on all the three parameters.

False Rejection Rate (FRR) is the measure of genuine samples rejected and False Acceptance Rate (FAR) is the measure of imposter samples accepted. Equal Error Rate (EER) is the value when FRR is equal to FAR. The equations for these three parameters are given below,

$$FAR = \frac{Wrongly\ accepted\ individuals}{Total\ number\ of\ wrong\ matching} \quad (1)$$

$$FRR = \frac{Wrongly\ rejected\ individuals}{Total\ number\ of\ correct\ matching} \quad (2)$$

The accuracy of the biometric authentication system is given by the following,

$$Accuracy(\%) = (100 - \frac{FAR(\%)+FRR(\%)}{2}) \quad (3)$$

The accuracy of the system increases if the value of False Rejection Rate (FRR), False Acceptance Rate (FAR) is decreased.

Below is a reference to the comparative illustration in the form of tables mentioning the techniques adopted or recommended by various researchers as a part of their work and the relevant gap that has been identified accordingly.

Table 1 shows the comparative research analysis of various palmprint recognition approaches whilst the Table 2 demonstrates the various techniques used for palmprint recognition and the evaluation metrics used.

Table 1: Comparison of various palmprint recognition approaches.

S. No	Paper Title	Feature Extraction Technique	Matching Technique	Outcomes	Research Gap
1.	An Efficient System for Palm Print Recognition using Ridges (George et al., 2014)	Minutiae extraction technique	Cascade filter method	With ridge features reduce the computational complexity and hence to increase the matching speed and accuracy	Does not support partial palm Prints
2.	Texture based Palm Print Recognition using 2-D Gabor Filter and Sub pace Approaches (Jaswal et al, 2015)	2D Gabor filter, PCA and LDA	Euclidean Distance	Higher accuracy (91%) in terms of correct recognition rate and low computation time.	The combination of the three different classifiers is little more complexity.
3.	A Robust Palmprint Identification System Using Histogram of Oriented Gradients and Multi-classifiers (Meraoumia et al., 2015)	Histogram of Oriented Gradients (HOG) descriptors	Fusion of Radial Basis Function (RBF), Random Forest Transform and Support Vector Machine (SVM)	Fusion of RBF-SVM combination is higher accuracy (99.342%)	The research takes more computational time.
4.	Hybrid DWT-DCT based Method for Palm-print Recognition (Varshney et al., 2014)	Hybrid DWT-DCT	Euclidean Distance	Higher accuracy (94.44%) using IITD Touchless Palm-print Database and reduced computational cost.	This research is worked on small database.
5.	A New Hybrid Approach for Palm Print Recognition in PCA Based Palm Print Recognition System (Kaushik et al., 2016)	Gabor Filter, PCA, 2D-LPF	KNN Classifier	98% of accuracy with less complexity in recognition of palm print	This technique is difficult in feature extraction methods.
6.	Gabor Filter and Texture based Features for palmprint recognition (Younesi et al., 2017)	Gabor Filter and Texture based Features	KNN Classifier	The algorithm achieves the higher accuracy (99.81%) performance in palmprint identification.	This method needs to reduce the error rate further.
7.	Palmprint Verification Based on Textural Features by Using Gabor Filters Based GLCM and Wavelet (Nezhadian et al., 2017)	GLCM and DWT	KNN classifier	The technique obtains 98.75% accuracy with less ERR.	

Table 2: Comparison of various palmprint recognition techniques and evaluation metrics used

S. No	Author	Proposed Method	Evaluation Metrics used	Limitations
1	Fei et al., (2016)	Half- Gabor Filter	Error rate, False Acceptance rate and Genuine Acceptance rate	Computational Complexity and Less Accuracy
2	Li and Kim, (2017)	Local Micro-structure Tetra Pattern	Standard Deviation and Recognition Rate	Impossible to extract the local descriptor in low or high contrast conditions, Distortion issues, Occlusion issues
3	Chin et al., (2014)	Random Tiling and an equal-probable 2N discretization scheme	Genuine Acceptance rate, Mean and Standard Deviation	Less Accuracy and failed to lower the error rate
4	Hong et al., (2014)	Weighted histogram of oriented gradient for locally selected pattern	False Rejection rate, False Acceptance rate and Genuine Acceptance rate	Low recognition problem
5	Morales et al., (2016)	Smart Regions of Interest, Orthogonal Line Ordinal Features, SIFT, DSIFT	Error rate and Detection rate	High Error rate and low Recognition problem
6	Gupta et al., (2016)	Quality estimation algorithm	CRR, EER, FAR, FRR	Recognition problem
7	Hong et al., (2015)	Multispectral palm print recognition	False Rejection rate, False Acceptance rate and Genuine Acceptance rate	Recognition rate
8	Latha &Prasad, (2017)	Haralick features, 2D-Gabor and 2D-log Gabor filters	False Rejection rate, False Acceptance rate	Recognition Accuracy and Error rate
9	Mu et al., (2011)	Complex directional wavelet and local binary pattern	Identification accuracy Identification time	Computational complexity

4. CONCLUSION

It is a fact that biometrics as a technology is thriving and is under tremendous focus by the research fraternity. With consumer electronics as a big consumer of the biometric technology these days, extensive research is being conducted at various scales to bring in light weight solutions that have user friendly interfaces combined with more emphasis on data security and having increased accuracy rates as a distinctive outcome.

Out of the four types of feature extraction and evaluation methodologies, the texture features extraction and evaluation is one area that is getting more attention considering the availability of the 3D data that will reduce the error rates to a great extent. However, not much research material on palmprint technology was found on the implication of the texture variation on the palm surface that might have been caused due to the palm being exposed to extensive wear and tear due to excessive use of palm in manual physical work without necessary protective gear on the palms.

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