Contactless Palmprint Verification System using 2-D Gabor Filter and Principal Component Analysis

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Abstract: *The palmprint verification system is gaining popularity in the Biometrics research area. The palmprint provides many advantages over other biometric systems such as low-cost acquisition device, high verification accuracy, fast feature extraction, stability, and unique characteristics. In this research article a new palmprint verification model is proposed using Sobel Edge Detection, 2D Gabor Filter, and Principal Component Analysis (PCA). The proposed new model is tested with the Indian Institute of Technology Delhi (IITD) palmprint database. The experimental results of the proposed new model achieves 99.5% Total Success Rate and 0.5% Equal Error Rate. The experimental result confirms that the proposed new model is more suitable compared to other existing biometric techniques.*

Keywords: *Biometric, palmprint, 2-D gabor filter, PCA.*

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1. Introduction

Biometric is the science of calculating and analysing physiological and behavioural data. Biometrics recognition systems use behavioural and physiological data for validation. The fingerprint, iris, face, palmprint, ear etc., are classified as physiological characteristics and signature, gait, keystroke etc. are classified as behavioural characteristics. The behavioural and physiological biometric are unique and applied for biometric applications. The palmprint based biometric verification technique has many advantages over other biometric approaches such as:

a) Works in low resolution imaging.
b) Low cost.
c) Stable structural feature.
d) Fast feature extraction.
e) High verification accuracy.
f) High user acceptability.

The palmprint recognition is a biometric technology which provides effective and reliable personal identification.

Palm is an inner surface of a hand and a palm contains three types of lines that are flexion creases, secondary creases, and ridges. The flexion creases are known as principal lines and secondary crease are called as wrinkles. The principal lines and the secondary lines are shaped between the 3rd and 5th months of the pregnancy of a woman [4]. These principal and secondary lines are identified as a feature in palm print verification. Some researchers have been using principle lines. Few researchers have been using ridges and minutiae in palmprint recognition system. Researchers have been working on high resolution images as well as low resolution images for biometric applications. The high resolution images are mainly used in criminal detection and forensic purpose [15]. Low resolution images are mainly used in automatic attendance, gate entry, and public authentication applications. Generally high resolution image refers to 400 dpi or more and the low resolution image refers to 150 dpi or less. Most of the palmprint-based identification techniques have been using line based technique, subspace based technique, and statistical technique.

The scientists have been developing efficient palmprint recognition technique using touch-less biometric system for effective source image acquiring, for hygiene and also due to various social reasons. Palmprint recognition approaches normally use natural light for image acquisition. The design and development of a touch-less system is a very complicated task. There are few important points noticed while designing a touch-less biometric system. The hand will not physically be in contact with the sensors. So, the distance between the sensor and hand may vary in real time. The uncertainty of difference in distance is an important factor in palmprint verification. The end user requires proper instructions for placing the palm in a suitable direction and locations before the camera. The lighting condition of the particular room is another important factor in the palmprint identification model. Thus, a new palmprint model is proposed to recognize the palmprint images at various distances of the palm and normal lighting conditions.

2. Related Works

Ghandehari and Safabakhsh [9] compared Principal Component Analysis (PCA) and adaptive principal component extraction for the palmprint recognition. Initially, applied improved PCA for palmprint recognition and also used Adaptive principal component extraction. They have also shown mathematical models of PCA and Adaptive Principal component EXtraction (APEX). They used Euclidean distance and Hamming distance as classifiers. They achieved highest recognition rate 94.57% in PCA and 98.33% in APEX, by using Euclidean distance. They achieved highest recognition rate 95.91% in PCA and 98.67% in APEX, by using Hamming distance.

Hong *et al.* [10] applied Gabor transform and curvelet transform on images. Further, they applied Improved Differential Box Counting (IDBC) and calculated fractal dimension. They used Hamming distance as a classifier. They used PolyU palmprint database for experiment and found FRR=0.1%, EER=0.0074% with Green and Red spectra. Total identification time was 1512 MS for fused BDOC-BHOC.

Perumal and Ramachandran [15] proposed a multimodal biometric system based on the palmprint and finger knuckle print ie. First they enhanced the images then extracted the Scale Invariant Feature Transform (SIFT), Speeded Up Robust Features (SURF) and frequency feature from the images. SIFT and SURF is used to extract the local features of finger knuckle print. Then they make fusion score and used this fusion score in matching and verification. They achieved FRR 0.83%, FAR 0.761%, and 99.541 % accuracy in proposed method.

Doublet *et al.* [7, 8] applied preprocessing in segmented palmprint image and applied Gabor filter bank for feature extraction. They calculated Error Rate=1.7% and 1.5%. They used 49 samples for their experiment.

Vijilious *et al.* [19] developed an approach for extracting palmprint feature by using non-subsampled contourlet Transform and Orthogonal Moments. They applied pre-processing and then segmented Region of Interest (ROI) from the hand image. Further, they extracted feature from the segmented ROI. They used CASIA Palmprint database for their experiment. They achieved 95.2% accuracy.

Ribari and Marˇceti´c [16] created an approach based on Gabor filter on the colour palmprint image. They decomposed colour image into R, G, and B components and then applied Gabor filtering and thresholding in each component. They used generalized Hamming distance as a classifier. They achieved 98.71% accuracy.

Sanchez-Reillo *et al*. [17] developed a biometric identification based on hand geometry. They fixed platform which had six tops that guided the position of the hand. They used a Charge Coupled Device (CCD) colour camera for image capturing. Then they applied preprocessing on the palm image. They divided the measurement algorithm in four different categories. They measure the width of four fingers at different-heights. After that the height of fingers and palm were calculated. The calculated distance between the middle point of the finger and the middle point of the straight line between the inter finger point. Finally, they measured the angle between the inter finger points and the horizontal. They achieved highest success rate 86% in Euclidean distance and 88% in Hamming distance.

Xuan *et al*. [20] modelled a palmprint recognition based on 2D-Gabor wavelet on contact palmprint. They used pulse-coupled neural network for feature extraction and classification by support vector machine. They achieved a Correct Classification Percentage (CCP) 97.37% in experiment 1 and CCP 95.40% in experiment 2. The average processing time was 1.44 seconds.

Kong *et al*. [12] utilized 2-D Gabor filter for palmprint feature extraction. They used a scanner for palmprint acquisition and pre-processed the palmprint image. Moreover, they analysed texture using Gabor feature extraction. They observed filter 11 is the best out of 12 filters in term of accuracy.

Zhao *et al*. [22] applied 2D PCA technique for features extraction from palmprint and used Modular Neural Network (MNN) as a classifier. They used PolyU palmprint database for experiment. They achieved highest recognition accuracy=99.27% in 2DPCA+PCA with 4950 modules.

Charfi *et al*. [3] created a bimodal biometric system by combination of hand and palmprint. They used SIFT for feature extraction and calculated the matching score. The matching score used for final result that is either accepted or rejected. They used Indian Institute of Technology Delhi (IITD) palmprint database for experiment and they achieved FAR=0.85%, FRR=3.55%, RR=94.05%, and EER=2.50%.

Zuo *et al*. [21] developed a bimodal based palmprint and face recognition using 2D PCA, applied the 2D-Gabor Filter-Principal Component Analysis (2DPCA-AMD) on the PolyU palmprint database and achieved a recognition rate of 97.67%.

Chen *et al.* [5] created a palmprint recognition algorithm Harris synthetically method. First they applied Harris algorithm for getting corner in palmprint image. Then they applied distance and orientation features to interconnect the corner points with lines and optimize the result. They used Fuzzy block for increasing the match probability. They used PolyU palmprint database for experiment. They achieved EER 0.30% in proposed approach and EER 3.79% in classic Harris approach.

3. Proposed System

The proposed system is a new Two Dimension Gabor Filter and Principal Component Analysis (2D GF-

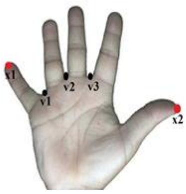
PCA) consisting of Binarization, Contour Analysis, Sobel Edge Detector, 2D-Gabor Filter, and PCA. The proposed approach utilizes advantages of Gabor filter and PCA. The Gabor filter allows unrestricted posture of palmprint images and PCA allows strong data representation for pattern recognition.

3.1. Segmentation

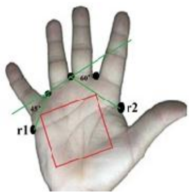
The following stages are involved in finding ROI from hand images.

1. Extracting the palm by removing the background.
2. Find left peak point x1 and right peak point x2, and find valley point v1 and v2 (Figure 1-B).
3. Draw a line which passes through v1, v2 point.
4. Make a line starting from point v1 with slope of 45 degree at the last-point of hand r1. Draw line starting from point v2 with slop of 60 degree at last point r2 (Figure 1-C).
5. The ROI is extracted using middle point of r1, v1 and r2, v2, (Figure 1-D).

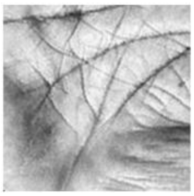
a) Original palmprint.



b) Reference points in palmprint.



c) Key points in pamprint.



d) ROI (Region of interest).

Figure 1. Palmprint ROI extraction.

After extracting ROI from the hand image, it is converted into greyscale image. The greyscale image is then enhanced using a median filter. The following steps namely pre-processing, 2D-Gabor Filter and extracted features using PCA are applied to the enhanced image as shown in Figure 2.

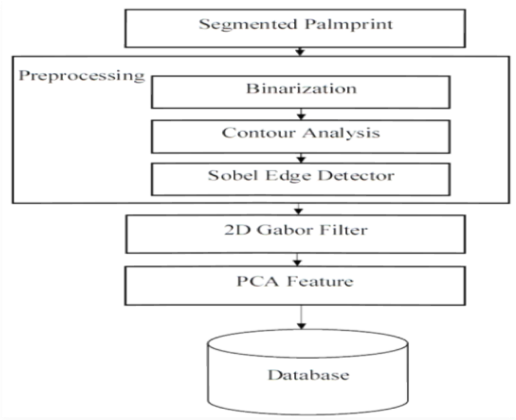


Figure 2. Flow chart of proposed 2D GF-PCA.

3.2. Preprocessing

The pre-processing is carried out using the segmented grayscale palmprint images obtained from the IITD Palmprint database. Median filter is applied in the segmented palmprint for enhancement. The median filter is used for minimizing the known and unknown degradation of an image. There may be degradations such as noise, motion, orientation, focus, and lighting while capturing an image by a camera without any instructions to the end user. Thus, the median filter is used for minimizing the degradation occurred in the source image captured using camera.

The median filter is represented in Equation (1), a process of replacing the value of a pixel by the median of the grey levels in the region of Sxy of that pixel.

$$\hat{f}(x,y) = \underset{(s,t)\in S_{xy}}{Median}\{g(s,t)\} \tag{1}$$

Further, the enhanced image is converted into a binary image using approximation. Moreover, contour points are identified from the binary image and edges are detected using Sobel edge detector [2].

3.2.1. Binarization

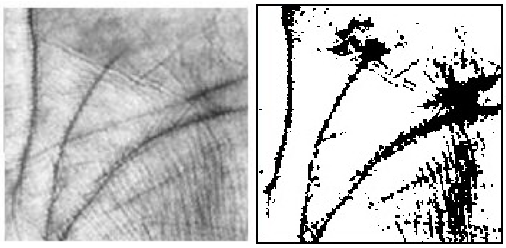
The first step in the pre-processing step is the binarization of a segmented palmprint. binarization is one of the most important steps in image processing. A binary image is a digital image represented by the values of either 0 and 1, i.e., either a black or a white pixel. Binarization process refers to the conversion of a grey-scale image to a binary image. which is an important pre-processing stage in most of the document analysis and system understanding methods. The binarization also plays an important role in segmentation and Optical Character Recognition (OCR) also. The following Figure 3-B, is a binary image obtained from the source image of following Figure 3-A.

3.2.2. Contour Analysis

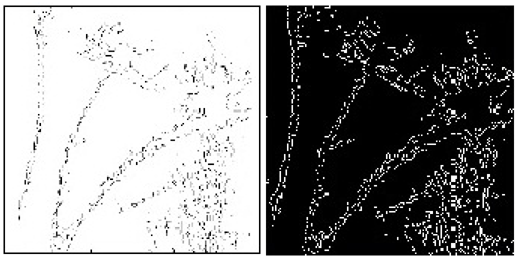
The contour analysis is applied to digital images for extracting their boundary line. The contour analysis is applied on the binarized palm image. Contour points detection is mainly used in preprocessing for removing noise and deleting the redundant points from the binary image in the following Figure 3-C.

3.2.3. Edge Detector

Edge detection is a method of recognizing and tracing sharp discontinuities in an image. The discontinuities are sudden changes in pixel intensity which characterize boundaries of objects in an image. The edge detection algorithm is grouped into two sub categories, Gradient and Laplacian. The gradient edge detection method detects the edges by looking for the maxima and minima in the first derivative of the image. The Laplacian method looks at the zero crossings in the second derivative of an image to find edges. The Sobel edge detector is used in the proposed new model. It is a gradient edge detector. The following figure 3D shows the result of the edge detectors.



a) Segmented palmprint. b) Binary image.



c) Contour Points. d) Edge detection.

Figure 3. The preprocessing stages in palmprint.

3.3. 2D-Gabor Filter

The Gabor filter is a renowned isotropic filter. It gives many advantages like variation of rotation, translation, and illumination, which is raised by a capturing device and palm structure. Gabor filter gives higher flexibility in the definition of function shape, because of more general set of degree of freedom.

2D-Gabor filter is the common texture descriptor introduced by Gabor [12]. It helps to extract features by analyzing the frequency domain of the images. Gabor filter uses Gaussian function modified by the complex sinusoidal of frequency domain. The Gabor filter successfully works in both spatial and frequency domains and works in any number of dimensions. The Gabor filter works by taking result of Fourier transform of the image and multiply with the Gaussian function at the various frequencies and apply Inverse Fast Fourier Transform (IFFT) of the results. In this proposed method 2D Gabor filter is applied on the pre-processed image.

Gabor Filter Bank: Gabor filter contains Gaussian function which is modified by the complex sinusoidal of frequency domain as shown in Equation (2).

$$G(x,y) \equiv -e^{-\frac{(x-x_0)^2}{2\sigma_x^2}-\frac{(y-y_0)^2}{2\sigma_y^2}} e^{j(\omega_{x0}x+\omega_{y0}y)} \quad (2)$$

Where,

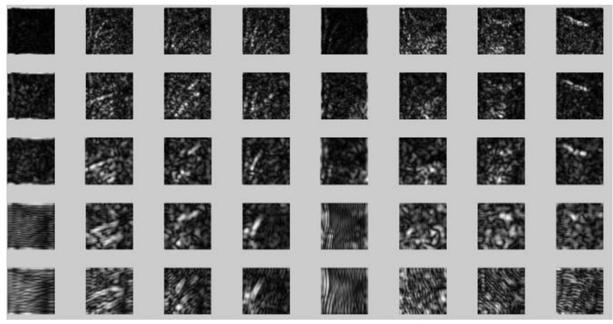
ω_{xo}=Centre frequency of x direction which the filter produces the greatest response.

ω_{yo}=Centre frequency of y direction which the filter produces the greatest response.

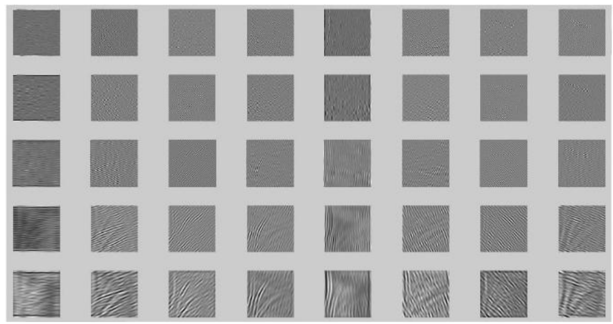
σ_x = Standard deviation of the Gaussian function along the x directions.

σ_y = Standard deviation of the Gaussian function along the y directions.

x, y = Coordinate of pixel position in to the image.



a) Magnitude of gabor filter.



b) Real parts of gabor filter.

Figure 4. Gabor filter bank.

For the real part of the Gabor filter is defined as Equation (3) [16].

$$\psi(x,y,\omega,\theta) = \frac{\omega}{\sqrt{2\pi k}} e^{-\frac{\omega^2}{8x^2}(4x^2+y^2)} (e^{i\omega x} - e^{-\frac{k^2}{2}}) \quad (3)$$

Where,

$x_1=(x-xo)\cos\theta+(y-yo)\sin\theta$

$y_1=-(x-xo)\sin\theta+(y-yo)\cos\theta$

(xo, yo) = The center of the function.

ω = The radial frequency in radians per unit length.

Θ = The orientation of the Gabor function in radians.

$k = \sqrt{(2\ln 2)}\ ((2\delta+1)/(2\delta-1))$.

The IITD database considered for the experiment consists of 300*300 segmented images. Total of 40 Gabor filters (8 orientations and 5 frequencies) are used in this experiment. The following Figure 4 shows the frequencies and orientations of these Gabor filters.

3.4. PCA Feature Extraction

PCA is used to analyze data for recognizing patterns and finding patterns for reducing dimensions for a set of data with minimum loss of data.

PCA also known as Karhunen-Loeve expansion, is a typical feature extraction data representation method. PCA is a typical feature extraction method and PCA is mainly used in the areas of pattern recognition and computer vision [14]. PCA is a simple and powerful technique. PCA is efficiently used for dimension reduction vector for recognizing the palmprint image.

Sirovich and Kirby [13, 18] first used PCA for the representation of human faces. They said that any face image might be almost recreated as a weighted sum of a small collection of images that define a facial basis and a mean image of the face (Eigen faces). PCA is a statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components. PCA is a mathematical procedure that uses linear transformations to map data from high dimensional space to low dimensional space [6]. The low dimensional space can be determined by Eigen vectors of the covariance matrix.

4. Experiment and Results

4.1. Palmprint Databases

IITD database [11] is used in this experiment. Using this database, performance of the proposed technique is evaluated.

4.2. IITD Database

The IITD palmprint image database contains left and right hand color images of 230 people of the age groups 14 to 56 years. Six palmprint samples of both hands had been taken from each person. All the hand images of this database had been taken by contactless CMOS camera and saved in a JPG format. The segmented image of both right and left hand images are provided in the IITD database which is stored in grey scale BMP format with a dimension of 150X150. These segmented palmprint images are used for the experiment.

4.3. Verification Rate of Proposed System

Various Equal Error Rate (EER), False Acceptance Rate (FAR), False Rejection Rate (FRR) and Total Success Rate (TSR) are used for evaluating the proposed new model for verification. In any biometric system, the FAR determines the rate of invalid persons who are incorrectly accepted, while FRR determine the total rejection rate for the right persons. TSR and EER are used as an evaluation standard, they are defined in the following Equations (4) and (5).

$$TSR = (NTM / TNA) \times 100\% \tag{4}$$

$$EER = (NWM / TNA) \times 100\% \tag{5}$$

NTM=Number of true matching,
NWM=Number of wrong matching,
TNA=Total Number of Attempts.

The following Table 1 shows TSR and Table 2 shows EER which is obtain from the experiment. It can be observed that the 2D-GF-PCA based method can recognize palmprint quite correctly. According to Tables 1 and 2 it is observed that the proposed method is more accurate than others because the proposed palmprint verification system gives a higher TSR. The value of TSR =99.50%, EER =0.50% and this newly proposed verification technique takes an average time=3.016 seconds for recognition.

Table 1. Comparison of total success rate.

Verification rate	TSR (Total Success Rate) in %
PCA[9]	95.91
PCA [1]	96.90
PCA with Reduced Dimensionality[1]	98.80
SIFT for palmprint [3]	94.05
2D-GF-PCA	99.50

Table 2. Comparison of equal error rate.

Verification rate	EER (Equal Error Rate) in percentage
Gabor filter [7]	**1.50**
Gabor Filter [8]	1.70
SIFT for palmprint [3]	2.50
2D-GF-PCA	0.50

Table 3. Time for palmprint recognition.

Palmprint	Time for recognition in seconds
P1	3.63
P2	2.92
P3	3.13
P4	3.16
P5	2.24
Average time	3.016

According to the following Table 2 the experimental result shows that the proposed method has more correct than other because of the proposed palmprint verification system give lowest EER.

Total verification time taken by five different palmprint images and calculated average verification time taken by the proposed model are shown in Table 3. The proposed method takes 3.016 seconds average time for palmprint verification which is comparatively faster than other techniques. The experiment results confirm that the proposed new palmprint verification model is an effective model for real time palmprint verification system.

From the Table 1 it is observed that the proposed technique has highest total success rate and the Table 2 shows the proposed new model has highest accuracy compared to other techniques. Table 3 shows the average time for palmprint recognition.

5. Conclusions

Touchless biometric applications have several advantages compared to the touch based biometric applications. A new touchless biometric palmprint verification model using segmentation, edge detection, 2D-Gabor filter, and PCA is proposed in this research article. The IITD palmprint database is used in this experiment. Performance of the proposed technique is evaluated using the IITD database. The performance analysis shows that the average indices for all functions are relatively good. The experimental results are compared with the four latest palmprint verification methods. The proposed 2D-GF-PCA achieved TSR 99.5% and ERR 0.5%. The proposed new method takes an average time of 3.016 seconds for palmprint verification, comparatively faster than other existing techniques. The experiment results shows that the proposed new palmprint verification method out performs other four latest palmprint verification models. In the future, the research will be focused on achieving 100% TSR in shorter verification time.

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