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Palmprint Recognition using Hybrid Features with Gabor Wavelet, Wavelet Moments and Random Forest Classifier

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Abstract – **The identification of individuals by their palmprints, considered as a new member of the family of biometric modalities, has become a very active area of research in recent years. The work done so far has been based on palmprints image representation techniques for better classification. This paper is divided into two phases, training phase and testing phase. In training phase there are three sub processes; pre-processing, feature extraction and dimensionality reduction. Pre-processing is done with the help of image resizing and RGB to Gray conversion. For feature extraction, we have used Gabor wavelet and wavelet moments. Principal Component analysis (PCA) is used for dimensionality reduction. The extracted features are then stored in database. In the testing phase the same process is done up to the PCA and then the similarity measure with database is done. Random Forest Classifier is used for similarity measure. The MATLAB image processing tool box is used to implement proposed Palmprint recognition system.**

Keywords – **Gabor Wavelet, PCA, RGB to Gray, Random Forest Classifier, Wavelet Moments.**

I. INTRODUCTION

Throughout the twentieth century, the word "biometrics" has been used almost exclusively in the very broad sense of "quantitative study of living things", particularly using statistical methods. It is with this in mind that the Biometric journal has been published since 1901 and that the International Biometric Society was founded in 1947.

The recognition of individuals has become more important in everyday human life. It insures the transactions of people by differing domains in order to ensure a relevant security [1]. In recent years, the practice of recognition systems remains limited to major sectors such as the military and other sectors requiring many applications such as the protection of access to a computer, a mobile phone, a USB key, an establishment, bank cards, etc. [2]. Many biometric technologies have been developed, all based on physiological and behavioural biometric identifiers such as: iris, voice, fingerprints, face, and signature. These are more reliable than conventional systems (key and password) in the recognition of a person because they are difficult to falsify. This is the reason why biometric systems are currently more and more solicited [3].

The palmprint recognition in the usual case, civil or commercial, is nothing other than a process of comparison of two images of full palmprints of controlled quality. The nature of the palmprint similar to that of digital has prompted researchers to exploit concepts and approaches designed for digital recognition [4].

In this study, a palmprint recognition system was chosen. This system uses the shape of the inner part of the hand for extracting the biometric identification characteristics of the individuals. These characteristics are permanent and stable throughout life, as unique for everyone. This work aims at the realization of uni-modal biometric systems based on the methods applied on binary vectors derived from Gabor wavelet and wavelet moments [5].

The technology of identification by their palmprint recognizes the individuals in the hands. This modality represents the inner surface of the hand very distinctive features, especially at the main lines [6]. In recent years, this new biometric descriptor based on this surface, called palmar fingerprint is started to use as a new biometric technology, several works show that this fingerprint can be used in the field of identifying people for robust recognition and precise [7-10]. Our proposed work consists of an identification system based on palmprint using a machine learning technique.

Figure 1: The palm of the hand [7]

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The palm of the hand is called the inner part of the hand (part not visible when the hand is closed) from the wrist to the roots of the fingers, as shown in Figure 1. Thus, the palm print is nothing but the impression (image) of the palm of the hand made by the pressure of the latter on a given surface. In other words, it can be defined as the model of the palm of the hand illustrating the physical characteristics of the pattern of its skin such as lines (main and wrinkles), dots, detail and texture.

Figure 2 shows the basic palmprint recognition system.

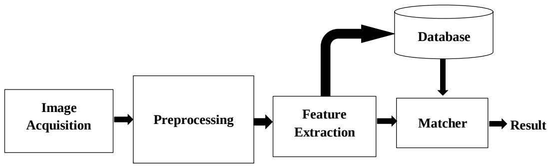

Figure 2: Basic block diagram of palmprint recognition system

II. Proposed Method

Palmprint recognition system is developed using Gabor Wavelet, Wavelet Moments, Principal Component Analysis (PCA) and Random Forest Classifier. The proposed flow for this research work is shown in Figure 3.

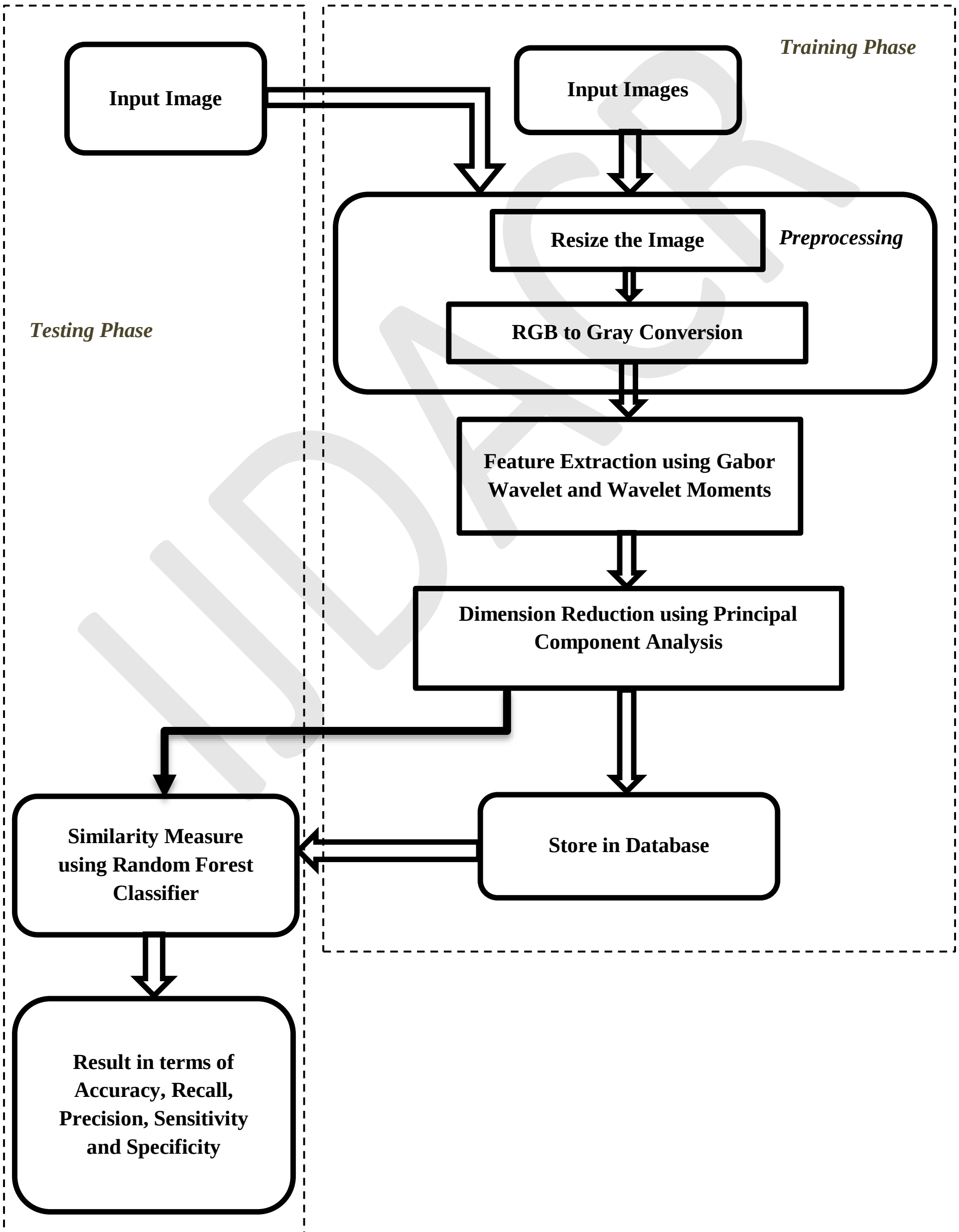

Figure 3: Flowchart for training and testing process for palmprint recognition

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As per the flow diagram it is clear that there are two phases of this research; training phase and testing phase.

Training Phase

In the first step of training phase we take input images one by one. Then the image is fed into Pre-processing block. Preprocessing is done with the help to two sub processes namely; Resize the image and RGB to Gray conversion. Since most of digital filters work on 2-dimensional data rather than multi-dimensional data, so RGB to Gray conversion is used. Moreover Histogram Equalization method is used for the equalization of image pixel intensity. Now the preprocessed image data is fed to Feature Extraction block. This block also contains two processes that are used for feature extraction namely; Gabor wavelet and wavelet moments. Principal Component Analysis (PCA) is used for dimension reduction. Principal component from the transformed output of features is extracted. This principal component is stored in the database. This all is done in the training process.

Testing Phase

In the testing phase an input image is processed similar to training phase. Pre-processing and Post-processing are done same as training phase. And the principal component extracted from the Post processing is matched using random forest classifier method with other principal components present in the database. And the recognition is completed using the parameters namely; Accuracy, Recall, Precision, Sensitivity and Specificity.

Pre-Processing Block

The steps involved in pre-processing are shown in Figure 2. The details are as follows:

1. The input image to this block is resized using the inbuilt resize function available in MATLAB. We have resized the image to 250×250 pixels.
2. After resizing, the RGB image is converted to a grey scale image using rgb2gray function.

Feature Extraction Block

Gabor Wavelets

Gabor's Eye, developed by Dennis Gabor, is extensively used as a treatment of images because the Gabor wavelets salient properties: the localization frequency and selectivity in orientation. Frequency representations and orientation of Gabor are according to human visual system [11]. The articles [12] (the first is in Nature) indicate that representation by Gabor's wavelets of palmprint images irrespective of variations in illumination or changes of palmprint expressions. The Gaussian envelope for palmprint recognition is represented as follows:

$$\psi_{u,v}(z) = \frac{\|K_{u,v}\|^2}{\sigma^2} e^{\frac{\|k_{u,v}\|^2 \|z\|^2}{2\sigma^2}} \left[e^{ik_{u,v}z} - e^{-\frac{\sigma^2}{2}}\right] \quad (1)$$

Where $z = (x; y)$ is the coordinate point $(x; y)$. Where u and v are orientation and frequency respectively for kernels of Gabor. $\|.\|$ is the standard operator and σ is standard deviation of the Gaussian envelope.

The Gabor wavelet is the representation of convolution product of frequency and orientation claimed from equation (1). The convolution of image I and of a kernel of Gabor $\psi_{u,v}(z)$is defined by:

$$G_{u,v}(z) = I(z) * \psi_{u,v}(z) \quad (2)$$

The interest of using Gabor's filters to extract palmprint features is capturing palm information in orientations and resolutions. In addition, they are invariant of illumination, distortions and variations in scale. In fact, the convolution of an image with 40 nuclei of Gabor (5 scales and 8 orientations) leads to 40 amplitude maps and 40 phase cards similar size as the original image. Therefore, if only the amplitude response is considered, "Jet" and it has been widely used in the oldest systems, such as the DLA and the EGBM. Note that these are methods based on the characteristic points which must be detected very precisely. Several metrics have been tested for characteristics based on Gabor and the one that is most often used is the cosine distance.

Wavelet Moments

In the wake of applying Gabor wavelet on the image with distinctive orientation at diverse scale, we acquire following array [13]:

$$E(m,n) = \sum_x \sum_y |G_{mn}(x,y)| \quad (3)$$

Where, $m = 0,1,\ldots,M-1$; $n = 0,1,\ldots,N-1$

It is assumed that we are interested in images or regions that have homogenous texture, therefore the mean and standard deviation are expressed as [13]:

$$\mu_{mn} = \frac{E(m,n)}{P \times Q} \quad (4)$$

$$\sigma_{mn} = \frac{\sqrt{\sum_x \sum_y (|G_{mn}(x,y)| - \mu_{mn})^2}}{P \times Q} \quad (5)$$

A feature vector f_g (texture representation) is created using μ_{mn} and σ_{mn} as the feature components [13, 14]:

$$f_g = (\mu_{00}, \sigma_{00}, \mu_{01}, \sigma_{01} \ldots \ldots \mu_{45}, \sigma_{45}) \quad (6)$$

Dimension Reduction using Principal Component Analysis (PCA)

Dimension Reduction of palmprint features is done using the PCA method. Let there are R images in the training set and each image X_i is a 2-dimensional

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IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 7, Issue 01, August 2018)

array of size $m \times n$ of intensity values. An image X_i can be converted into a vector of D ($D = m \times n$) pixels, where $X_i = (x_{i1}, x_{i2}, \ldots, x_{iD})$. The rows of pixels of the image are placed one after another to form the vector.

Define the training set of R images by:

$$X = (X_1, X_2, \ldots, X_R) \subset \Re^{D \times R} \tag{7}$$

The covariance matrix is defined as follows:

$$\text{con (X, Y)} = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{(n-1)} = \emptyset\emptyset^T \tag{8}$$

Where,

$\emptyset = (\emptyset_1, \emptyset_2, \ldots, \emptyset_R) \subset \mathcal{R}^{D \times R}$ and $\bar{X} = \frac{1}{(n-1)} \sum_{i=1}^{n} X_i$ which is the mean image of the training set. The dimension of the covariance matrix Γ is $D \times D$. Then, the eigenvalues and eigenvectors are calculated from the covariance matrix Γ. Let Q= $(Q_1, Q_2, \ldots, Q_R) \subset \mathcal{R}^{D \times R} (r < R)$ be the r eigenvectors corresponding to r largest non-zero eigenvalues. Now, each of the images of the training set X_i is projected into the eigenvector to obtain its corresponding feature $Z_i \subset \mathcal{R}^{D \times R}$ which is defined as follows:

$$Z_i = Q^T Y_i, i = 1, 2, \ldots, R \tag{9}$$

Where, Y_i is the reduced dimension image of X_i.

Similarity Measure using Random Forest Classifier

A random forest is a classifier containing of one group of structured tree predictors $[T(x, \ominus_k), k = 1, \ldots.]$ where the $[\ominus_k]$ are random vectors of identical distributions and where every tree provides a unit poll for the furthermost common class of each entry x.

The main advantage of this structure is that it avoids the danger of over-learning for any method of prediction based on induction. BREIMAN [167] shows that when the number of trees involved in the prediction forest increases, the generalization error rate converges to a limit value, of which an upper bound can be estimated on the basis of the characteristics intrinsic features of the forest.

The RF classifier is formed by a number of base learners and each base learner acts as an independent binary tree which adapts recursive partitioning. The best feature is selected by Gini index, which is used to build the binary tree. It has the following advantages:

- RF is one of the most accurate classifier in present scenario.
- Overfitting is reduced due overgrowing the trees hence it is ease to handle.
- It accepts a large number of input variables without any deletion of the variables.
- The number of base learners is the only setting parameter to give the highest accuracy.

If the marginal function of a random forest $T(X, \ominus)$

$$mr(X, Y) = P_{\ominus}(T(X, \ominus) = Y) - \max_{j \neq T} P_{\ominus}(T(X, \ominus) = j) \tag{10}$$

Which represents the confidence level of the ranking established by the trees of this forest on the population (X, Y), measured by the difference of probability between the prediction of the correct class Y and the best class erroneous j ≠ Y, one can define the prediction value of a game of trees {T (x, Θ)} by the mathematical expectation of this function

$$s = E_{x,y}[mr(X, Y)] \tag{11}$$

The dependency between trees in a forest ρ (⊖,⊖ ') is measured by the correlation between their gross marginal functions, and it is evaluated for fixed and distinct parameter values ⊖,⊖. By means of these definitions, an upper limit to the error in generalization of any random forest is given by the relation.

$$TEG \leq \bar{\rho}(1 - s^2)/s^2 \tag{12}$$

III. Simulation And Results

The simulation is carried out by using MATLAB software image processing toolbox.

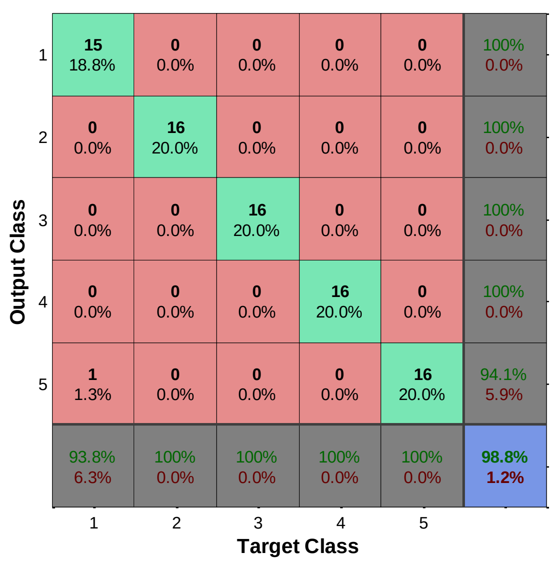

Figure 4: Confusion matrix plot for palmprint recognition using random forest classifier

The row and column are the class of CASIA database. There are 5 set of classes and each class having different set of detection. For training only

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16 samples are taken from every set. The confusion plot indicates the accuracy i.e. 98.8% for proposed algorithm.

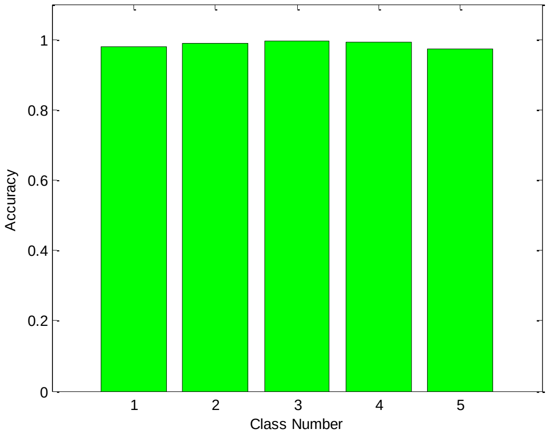

Figure 5: Accuracy graph for Random Forest Classifier based approach

Table 1: Accuracy for Random Forest Classifier based approach

Class Number	Accuracy
1	100%
2	100%
3	100%
4	100%
5	94.1%

Figure 6 shows the bar graph of accuracy for Random Forest Classifier based approach. The associated accuracy for this bar graph is shown in Table 1.

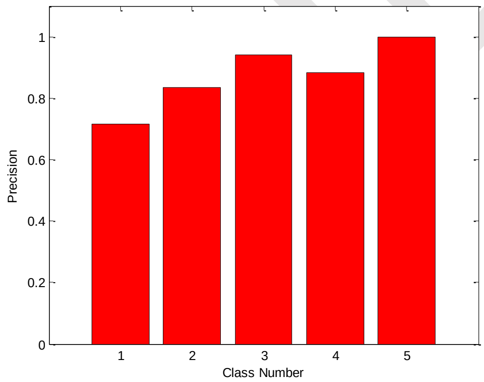

Figure 6: Precision graph for Random Forest Classifier based approach

Table 2: Precision for Random Forest Classifier based approach

Class Number	Precision
1	0.7143
2	0.8333
3	0.9412
4	0.8824
5	1.0000

Figure 6 shows the bar graph of precision for Random Forest Classifier based approach. The associated precision for this bar graph is shown in Table 2.

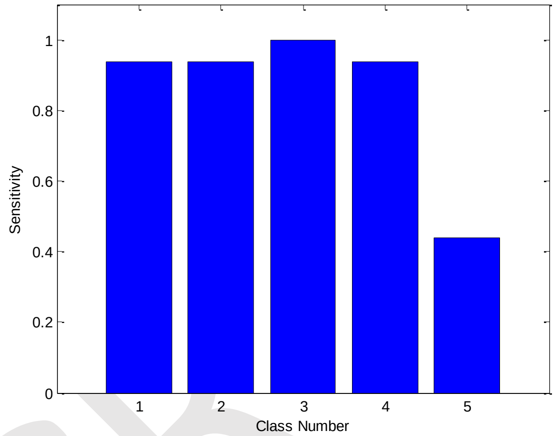

Figure 7: Sensitivity graph for Random Forest Classifier based approach

Table 3: Sensitivity for Random Forest Classifier based approach

Class Number	Sensitivity
1	0.9375
2	0.9375
3	1.0000
4	0.9375
5	0.4375

Figure 7 shows the bar graph of sensitivity for Random Forest Classifier based approach. The associated sensitivity for this bar graph is shown in Table 3.

IV. Conclusion

A training procedure is necessary to construct palmprint model in our approach, that is, the method is entirely dependent on the training set. Verification tests on our palmprint database are used to choose a group of optimal parameters for the proposed method. The proposed method with these appropriate parameters is used to perform accuracy test on our palmprint database and the palmprint database. There is another phase called testing phase is used for an image for which the similarity measure is done with the help of random forest classifier method. The experimental results demonstrate that the proposed approach can give a better performance in terms of accuracy, recall and precision.

Following developments can be made in the future:

- Multimodel biometric recognition system.
- Optimal palmprint based biometric recognition system.

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