Identification of Fingerprint Using Discrete Wavelet Transform in Conjunction with Support Vector Machine

Shahid Akbar , Ashfaq Ahmad , Maqsood Hayat

Department of Computer Science, Abdul Wali Khan University Mardan

Abstract:

Fingerprint recognition is mostly used in biometric and security system that are practically applicable in different fields of national defense organization for various safety measures. Looking at the importance of biometric system, a lot of efforts have been carried out for recognition of fingerprint, but still there exist some issues, which demand for more attention and exploration. In this regards, we attempt to develop a vigorous and reliable biometric system for recognition of fingerprint. The proposed computational model is developed using three discrete features extraction methods such as Discrete Wavelet transform, Principal Component Analysis and Discrete Cosine Transform. Two diverse nature of classification hypothesis are utilized namely: Support Vector Machine (*SVM*) and K-nearest neighbor. Three different benchmark fingerprint datasets and 10-folds cross validation are applied to evaluate the performance of the proposed model. The empirical results reveal that *SVM* has achieved outstanding performance using all the three benchmark datasets. It is ascertained that the predicted model may be useful and high throughput tool for academia and security related areas.

Key words: DWT; PCA; DCT; KNN; SVM; 10-folds.

1. Introduction:

The Word "**Biometric**" is derived from the Greek word which means "life to measure". Biometric deals with physiological or behavioral characteristics of an individual to identify human. Unlike the traditional password-based recognition methods, the biometrics system possesses unique, invariant, consistent, and reliable information to recognize an individual [1].

Among all biometrics techniques, fingerprint identification is considered one of the most mature and reliable technology because of its unique and distinct attributes.

Fingerprint recognition is commonly used for security system since last few decades and is considered one of the most realistic proofs of authentication all over the world [2]. A series of work have been carried out for fingerprint matching [3,4] ,fingerprint classification [5,6,7,8] and fingerprint alignment [9,10].Koichi et al., proposed a novel techniques based on phase based matching and feature based matching of weak and low quality images of *FVC 2002*, DB1 fingerprint dataset. The performance of the proposed system achieves efficient result than that of minutiae-based and the conventional phase-based algorithms [11].Bazen et al., estimated the high resolution directional field using Principal Component Analysis and also detected singular points of fingerprint images [12]. Likely, Yang et al., proposed an innovative filter design method for fingerprint image enhancement through modified Gabor filter (*MGF*) which is an improved version of traditional Gabor filter (*TGF*). The proposed MGF achieved high image enhancement consistency and more accurate in preserving the fingerprint image topography [13].Melo et al., combined Principal Component Analysis (*PCA*) and edge detection features to decide correctness of an acquired fingerprint image into a given database [14]. Similarly, Chikkerur et al., introduced time Fourier transform (*STFT*) Analysis for fingerprint image enhancement. The proposed approach shows improved recognition rate on *FVC2002*, *DB-3* fingerprint database [15].Furthermore, Pokhriyal et al., used Zernike moments (*PZMs*) and 2-D wavelet transform to extract global and local features from fingerprint image respectively. Wavelet transform using Sym8 filter achieved highest recognition rate of 95.79% among all considered filters [16]. Dale et al., introduced a model based on discrete cosine transform (*DCT*) for fingerprint matching, which divided the transformed image into different blocks, calculate the standard deviation of each block and form a feature vector of all blocks. Recognition rate of 100% is obtained for a typical threshold value [17].Ani et al., extracted global features from the fingerprint images based on *DCT*. [18].Similarly, Tewari et al., used *DWT*, Fast Fourier transform (*FFT*) and *DCT* to extract feature from the fingerprint images. The model was exercised on *FVC 2002* fingerprint database. *DFT* and *DCT* based feature space obtained better accuracy than that of *DWT* [19]. Similarly, George et al., introduced Transform Domain Fingerprint Identification Based system. Features are extracted by applying *DTCWT* at various levels. Among different levels, where level 7 achieved better recognition accuracy compared to the other levels [20].Alam et al., Combined Region of Interest (*ROI*) and *DWT* approach to extract feature vector to detect fingerprint [21].

In this work, we proposed a robust and intelligent computational model for fingerprint recognition. Features are extracted using three feature representation schemes *PCA, DWT,* and *DCT*. *K-NN* and *SVM* are used as classifiers. *CASIA* fingerprint database are used to evaluate the performance of classification algorithm.

The remaining paper is organized as follows: Section 2 represents the feature extraction techniques and classification algorithms. Section 3 presents Results and discussion. Finally conclusions are drawn in the last Section.

2. Materials and Methods

2.1) Datasets Description:

In order to develop a robust and reliable computational model we need a benchmark dataset to train and test the system. For this purpose we select *CASIA* Fingerprint Image Database Version_5.0 to evaluate our proposed model [22].In our work, we used three benchmark image dataset .where Dataset 1, Dataset2, Dataset3 consist of 40,100 and 200 set of fingerprint images respectively, containing equal number of instance for both left and right hand classes. All the images are stored in *BMP* format and having image resolution of 328*356 pixels.

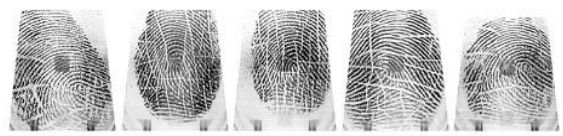

Figure 1. Samples fingerprint images from CASIA-V5

2.2) Principle Component Analysis (PCA):

Principal component Analysis is the most widely used feature extraction scheme for analyzing and identifying data based on the most distinguishing features [23, 14]. We used *PCA* to generate eigenvectors from calculated Eigen value of each image; obtained eigenvectors are orthogonal and represent the directions with maximum variation. It is described as follows:

Let us suppose, we have the X set of input images $[X_1 + X_2 \ldots \ldots \ldots \ldots \ldots . X_n]$.

Step 1: First calculate the mean of the images

$$X_{Mean} = \left(X_1 + X_2 \ldots\ldots X_n\right) / n \quad (1)$$

Subtract the mean image from each image in Db_image

$$X'_i = X_i - X_{Mean} \qquad i = 1, 2, \ldots, n \quad (2)$$

Step 2: Compute Covariance Matrix C_X:

$$C_X = (X'_i).(X'_i)^T \quad (3)$$

Step 3: Find out Eigenvectors $\{\Omega_1, \Omega_2, \Omega_3, \ldots\ldots\ldots\ldots \Omega_n\}$ and Eigenvalues $\{\lambda_1, \lambda_2, \lambda_3, \ldots\ldots \lambda_n\}$ of the Covariance Matrix C_X.

Step 4: Calculate Eigen-fingerprint:

$$[\varphi].\Omega_i = f_i \quad (4)$$

Where Ω_i represent eigenvectors and f_i are Eigen-fingerprints.

2.3) Discrete Wavelet Transform (DWT):

Discrete wavelet transform is one of most popular image processing tool that is used for feature extraction, detection, image compression and recognition purposes. *DWT* performs multi resolution analysis with localization in both frequency and time domains. *DWT* is employed in order to preserve the high-frequency components of the image. Wavelet transform has advantage of robustness, flexibility and less computational time over other transform [16, 24, 25].

Wavelet transform decomposes image into four subparts images which are Low-Low (*LL*), High-Low (*HL*), Low-High (*LH*), and High-High (*HH*). In our case two level *DWT* is applied on fingerprint image to extract more significant information of an image.

Two dimensional wavelet transform of an image is given as follows

$$DWT(j,k) \; \frac{1}{\sqrt{2^j}} \int_{-\infty}^{+\infty} f(x)\psi\left(\frac{x}{2} - k\right)dx \quad (5)$$

where j is the power of binary scaling and *k* is a constant of the filter.

In order to extract numerical attributes, we have used several statistics measures such as maximum, standard deviation, Euclidian distance, variance, skewness, log energy, and kurtosis.

2.4) Discrete Cosine Transform (DCT):

Discrete wavelet transform is much related to discrete Fourier transform. *DCT* alters images from time domain to frequency domain to de-correlate pixels, because fingerprint have high correlation and redundant information that reason high time complexity and high processing speed [26]. In our case for comparative analysis we evaluate *DCT* is applied on fingerprint to extract features; same Attributes like *DWT* are considered here to gather useful information.

2.5) K-nearest neighbor algorithm (Knn)

K- Nearest Neighbor is the most popular classification algorithm in area of pattern recognition and machine learning. K-NN is the simplest, Intuitive and fast prediction learning algorithm. That classifies objects based on the proximity of the training samples in the feature space [27, 28].

For each test image, Euclidean Distance is used to calculate the distance between the closest members of the training data set. The Euclidean distance formula is given in equation (7):

$$d(x,y)=\sqrt{\sum_{i=1}^{N}(x \quad y_i)^2} \qquad (6)$$

2.6) Support Vector Machine (SVM)

In pattern recognition, Support vector machine is classification algorithm that analyzes and classifies objects based on statistical theory.*SVM* is more efficient and fast hypothesis learner for identifying linear pattern as well as non-linear classification problems. In this model, we utilized SVM for binary class problem [29, 30].

Let we have **T** set of training data and n number of points,

$$T = \{(x_i, y_i) \overline{\ } x_i \in \mathbf{R}^p, y_i \in \{-1,1\}\}_{i=1}^{n} \qquad (7)$$

Where y_i indicating the number of classes that could be either 1 or -1 to which $x_i$set ofpoints. Hyperplane drawn for satisfying $\mathbf{X}_i$ number of points can be written as:

$$\mathrm{W.X} - b = 0 \qquad (8)$$

Where W represents normal vector to the Hyperplane, The parameter $\frac{b}{\|\mathbf{w}\|}$ determines the offset of the hyperplane from the origin along the normal vector W.

If the training data is linearly separable, we need to select a Hyperplane in such a way that can clearly separate data in two parts, so the required two hyperplanes are described by the following equations:

$$\mathrm{W.X} - b = 1 \qquad (9)$$

$$\mathrm{W.X} - b = -1 \qquad (10)$$

Then the distance $\frac{2}{\|\mathbf{w}\|}$between two hyperplanes is calculated. We need to minimize$\|$ W $\|$.To prevent data points from falling into the margin area, we add the following constraints:

$\mathrm{W.X_i} - b \geq 1$, for X_i of 1^{st} class

$\mathrm{W.X_i} - b \leq -1$, for X_i of 2^{nd} class.

It can be also written as,

$y_i(\mathrm{W.X_i} - b) \geq 1$, for all $1 \leq i \leq n$

2.7) Proposed Method

In this paper, we propose a vigorous, precise and efficient computational model for identification of fingerprint. Features are extracted using three different approaches, such as *PCA*, *DWT* and *DCT*. The proposed feature extraction techniques are tested on three different fingerprint image datasets .*K-NN* and SVM are utilized to evaluate the performance of the proposed system. 10 folds cross validation test is applied to assess the performance of the proposed model. Block diagram of the proposed system is depicted in figure3**.**Other performance measures are used to evaluate the discrimination power of the learning algorithms, which are described below:

$$Accuracy = \sum_{i=1}^{k} \left({}^{TPi}/_{N} \right) \qquad (11)$$

$$Sensitivity = \left(\frac{TP}{TP} + FN \right) * 100 \qquad (12)$$

$$Specificity = \left(\frac{TN}{FP} + FN \right) * 100 \qquad (13)$$

$$MCC = \frac{(TP*TN-FP*FN)}{\sqrt{([TP+FP][TP+FN][TN+FP][TN+FN])}} \qquad (14)$$

In classification, researchers have applied various cross validation tests in order to evaluate the performance of their prediction model. Among these cross validation test, jackknife test has been extensively used due to generation of unique results. Despite of its special characteristics, it is expensive with respect to time and space. In order to reduce computational cost along with the distinguishable attributes of jackknife test, we have applied 10-folds cross validation test. In 10-fold cross validation test, one fold is used for testing purpose and the remaining folds are used for training. The whole process is repeated 10 times and finally the results are combined.

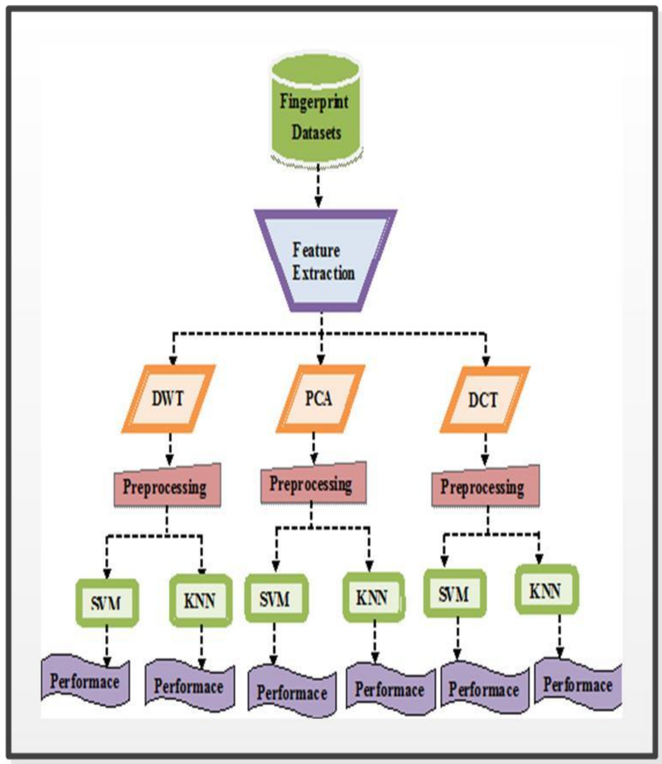

Figure.3. Framework of the proposed system

3.1) Prediction Performance using PCA Feature Vector

Success rates of all the three fingerprint datasets with *PCA* based feature space are listed in Table 1. In case of dataset1, *KNN* has achieved the highest performance than that of *SVM*. The obtained accuracy is *MCC* 0.75 on both 3rd and 5th nearest neighbor. In contrast, *SVM* has obtained an accuracy of 80%, sensitivity 90%, specificity 70%, and MCC 0.61.Using dataset 2, similarly, *KNN* has yielded 66.5%, 64%, 68%, and 0.32 accuracy, sensitivity, specificity, and MCC, respectively. Whereas, SVM has obtained an accuracy of 65%, sensitivity of 62%, Specificity of 68% and *MCC* of 0.29.In case of dataset3, the performance of *KNN* is not substantial compared to *SVM*. *SVM* has achieved 90.5%accuracy 89% sensitivity, 92% specificity, and 0.81*MCC*, while the accuracy of *KNN* is 65%.

3.2) Prediction Performance using DWT Feature Vector

The prediction performances of *SVM* and *KNN* in conjunction with *DWT* based feature space are listed table 1. Using dataset 1, the performance of *SVM* is quite promising compared to *KNN*. It has achieved an accuracy of 95%, where the sensitivity, specificity, and, MCC are 95%, 95%and 0.90%, respectively. On the other hand, *KNN* has obtained an accuracy of 90%, specificity 95%, sensitivity85% and MCC of 0.80. Still the performance of *SVM* is remarkable on both the dataset namely, dataset2 and dataset3. Its accuracy is 87% 87.5%, sensitivity 90%, specificity 85%, and 91.5% on dataset2 and dataset3, respectively.

3.3) Prediction Performance using DCT Feature Vector

The predicted results of the proposed model using *DCT* are reported in Table1.In case of dataset1,*SVM* has achieved the highest accuracy of 80% with sensitivity, specificity, and MCC of 70%, 85% and 0.60, respectively, whereas, *KNN* has obtained an accuracy of 77.5%,sensitivity of 75%, specificity of 80% and MCC of 0.55. The accuracy of *KNN* is 75%, while *SVM* achieved an accuracy of 72% on dataset2.In a sequel, the performance of *SVM* and *KNN* using dataset 3 are 82% and 71% accuracy. The other performance measures are also mentioned in Table 1.

The empirical results reveal that the performance of SVM is outstanding using *DWT*. In DWT feature representation method, the images are decomposed into different levels, so the optimal level of identification is important, because when the image is decomposed into high level consequently, redundant and irrelevant features are extracted, while in case of low level decomposition some salient features are missing. In this work, we have selected the level of composition 2 after investigation.

Table 1. Success rates of SVM and KNN using 10 fold cross validation test

Proposed Methods		SVM				KNN			
		Acc	*Spe*	*Sen*	*MCC*	*Acc*	*Spe*	*Sen*	*MCC*
DWT	***Dataset 1***	**95**	95	95	0.90	90	95	85	0.80
	Dataset 2	87	88	86	0.74	81	76	86	0.62
	Dataset 3	91.5	93	90	0.83	84	85	83	0.68
PCA	***Dataset 1***	80	70	90	0.61	87.5	80	95	0.76
	Dataset 2	65	62	68	0.29	66.5	64	68	0.32
	Dataset 3	**90.5**	92	89	0.81	65	35	96	0.39
DCT	***Dataset 1***	80	85	70	0.60	77.5	80	75	0.55
	Dataset 2	72	74	70	0.44	75	88	62	0.52
	Dataset 3	**82**	81	83	0.64	71	60	82	0.43

4. Conclusion

In this work, we propose an efficient and accurate security system for fingerprint recognition. In this regards, we have evaluated a comparative analysis of three feature extraction schemes such as DWT, PCA, and DCT. For classification purpose SVM and K-NN are carried out. To assess the performance of both the classifiers 10 folds cross validation is used. The experimental results illustrate that *SVM* has achieved the highest success rates are 95% and 91.5% using DWT feature space; respectively. It is ascertained that the proposed model might be helpful and useful for security purpose application in the area of biometrics.

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Authors Biography:

Shahid Akbar received his Bachelor degree in Computer Science & Information Technology from Islamic University of Technology, OIC, Dhaka, Bangladesh, in 2011. He is currently doing his MS degree in Computer Science from Abdul wali Khan University (AWKU), Mardan, Pakistan. His research interests include Pattern Recognition, Machine learning and Image processing.

Dr. Maqsood Hayat received his MCS degree from Gomal University, D I Khan, in 2004 and his MS degree in Software & System Engineering from Mohammad Ali Jinnah

University (MAJU), Islamabad, in 2009. PhD degree from Department of Computer & Information Sciences, Pakistan Institute of Engineering & Applied Sciences, Islamabad, Pakistan. His main research includes Machine learning and its application in Bioinformatics.

Ashfaq Ahmad received his MCS degree from IBMS/CS, Agricultural University Peshawar, in 2007. He is currently doing his MS degree in Computer Science from Abdul wali Khan University (AWKUM), Mardan, Pakistan. His research interests include Pattern Recognition, Machine learning and Image processing.