Finger Knuckle Biometric Authentication using Texture-Based Statistical Approach

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Abstract*—Reliable authentication techniques play major role in designing security applications. Initially, passwords and tokens are used for identifying the authorized user which are easily forgotten or stolen by others. Therefore, biometric is an evident and secure way of authenticating the user in most of the applications. Various biometric traits such as physical or behavioral characteristics of individual are used for identification. Finger Knuckle Print (FKP) is one of the new emerging modality used for recognition of an individual. Finger Knuckle is rich in texture, a contactless biometric trait with highly unique characteristics. In this work, Gabor filter, texture based statistical approach is used to extract the feature vector from each segmented FKP. In addition, K-nearest neighbor (KNN) algorithm is used to train the system for extracting the feature vector. PolyU database and IIT Delhi databases are used to test the proposed FKP biometric authentication. Proposed FKP biometric authentication technique is implemented and experimental results show that the average efficiency of the algorithm is 86.133% and 99.4% for IIT Delhi and PolyU finger Knuckle databases respectively.

Keywords—FKP, Feature extraction, Gabor Filter, Authentication, KNN

I. INTRODUCTION

Biometric is a physical or behavioral characteristics of an individual which is used in various applications for identification and access control. Various unique identifiers are fingerprint, iris, palm print, retina. DNA, teeth, Keystroke dynamics, and signatures. Recently the hand based biometrics are used in various real time applications due to the cost factor and stability. Fingerprint, finger texture, hand geometry, hand vein patterns, palm print and finger knuckle are commonly used hand biometrics traits **[1].** Among hand based biometric traits, the fingerprint is very popular in the biometric system and is used in access control and for attendance system. Some of the issues in using fingerprint are: *i*) easily spoofed by the attackers, *ii*) if the skin is wet or dry, then, it is difficult for sensors to detect, and *iii*) for most of the individuals working in agricultural lands the fingerprint features such as minutiae, ridges and valleys are not clear.

Finger knuckle print is been used as one of biometrics in during the last ten years**.** Finger Knuckle print (FKP) is the skin pattern of the back surface of the hand, which is highly rich in texture, unique in characteristics, contactless and less expensive. The back surface of the hand has three joints called phalangeal joints. The region which joins the finger and hand is known as Metacarpophalageal joint. The mid joint of the finger is called Proximal Inter-Phalangeal joint (PIP) or major Knuckle and the hinge joint in the tip is called as Distal Interphalangeal Joint (DIP) or minor knuckle. Various joints in the finger are shown in Fig. 1. The skin pattern of interphalangeal joints creates the dermal patterns consisting of lines, wrinkles, contours etc. Patterns of finger dorsum surface are highly unique in nature and are used in a biometric system for identification and authentication **[2, 3, 8].**

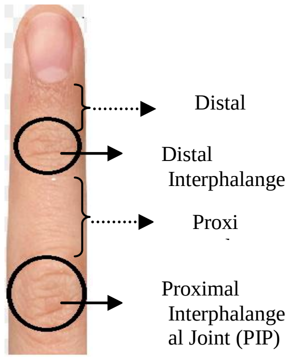

Fig. 1. Structure of Finger Knuckle

II. LITERATURE REVIEW

Finger Knuckle print recognition is used for personal authentication in **[4].** Features are extracted from the finger knuckle print using Randon coefficient technique and are stored in the database. Later for pattern recognition, the Radial Basis Function (RBFN) classifier is used to identify the genuine user. The recognition accuracy achieved in the proposed work is 97.25%. Sadhna and Hemansh [5], have discusses various recognition algorithms for finger knuckle print recognition. Subspace-based method, coding method, and fusion of algorithms are presented in [5]. Fusion methods produce high recognition rate.

Mourad et al [6], have proposed an efficient biometric-based personal authentication system using finger knuckle prints. The proposed work in [6] uses a novel method to extract the optimal discriminant features from the FKP images. In [6], the preliminary features are extracted using ID-log Gabor Filter and the Gabor filter bank is used to select the discriminant features. The dimensionality reduction algorithm Linear Discriminate Analysis (LDA) is used to reduce the dimensionality of the discriminant features and to enhance the quality of the FKP images. The nearest neighbors classifier based on cosine Mahalanobis is used for matching purpose. The proposed personal authentication technique reduces the Equal Error Rate [EER] for FKP images. A biometric authentication technique based on finger knuckle surface is proposed in [7]. In [7], the FKP extracts texture and hand geometric features from the finger knuckle. Geometric features based on Euclidean distance and ROI are extracted from the four fingers. The extracted features are normalized using Z-score and Min-Max. Among the Z-score and Min-Max, the Min-Max normalized images give better recognition rate. Finger knuckle authentication achieves 1.94 EER and decidability index of 2.35.Guangwei et al. have proposed reconstruction of the query finger knuckle print with dictionary learnt from the templates that are stored in the database. The aim of this work is to reduce the finger pose variations and also to reduce the enlarged image during matching. In [8], reduce an adaptive binary fusion is proposed to reduce false rejections. The Equal Error Rate (EER) achieved in [8] is approximately 0.22% and decidability index 4.48%. Kumar and Y. Zhou [9] have proposed a radon transformation approach for identification using finger knuckle orientation features. The proposed approach generates the knuckle codes based on the orientation feature of enhanced finger Knuckle image. The results based on the knuckle codes achieve promising results. In [9], the finger knuckle identification achieves the recognition rate of 98.6% and EER of 1.14%.

III. Proposed Methodology

The finger knuckle is used as a biometric trait for personal authentication. The image is acquired by capturing the finger knuckle using a camera. The captured images are preprocessed to remove the noisy data and the segmented sub-image is given as input to the next phase. The knuckle's local orientation features are extracted using Gabor filter, a statistical texture analysis approach. The texture information of the finger knuckle is converted to feature vector and stored in the database. The query finger knuckle's input vector is matched with the feature vector of the enrolled vector and the match score is computed using KNN classifier. Finally, the authentication decision is done based on the match score. The proposed finger recognition system is shown in Fig. 2.

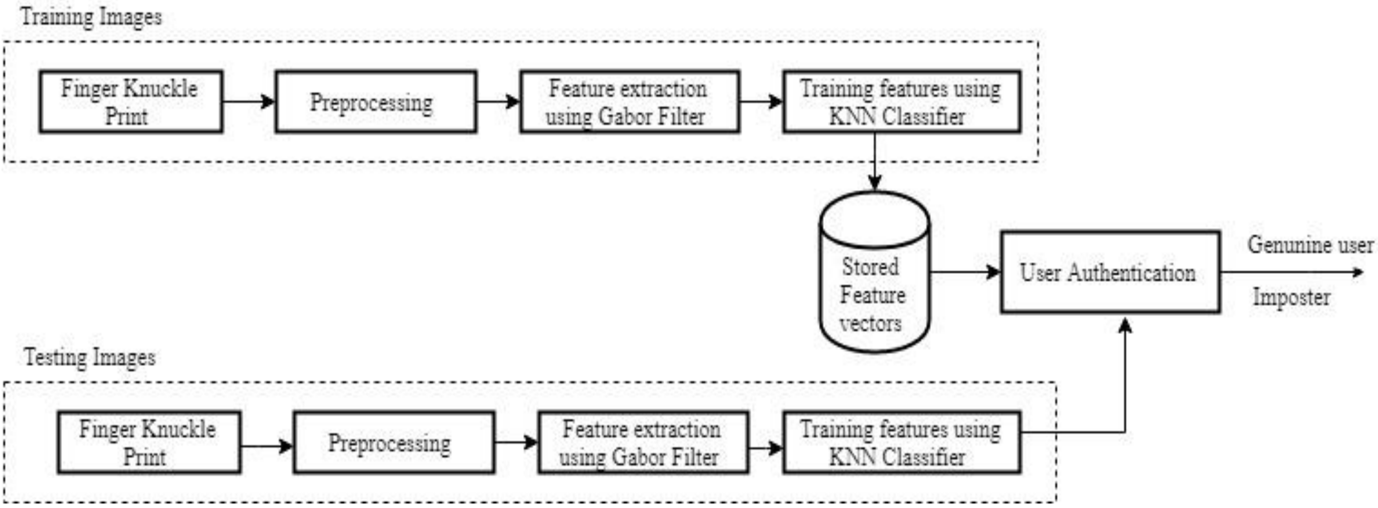

Fig. 2. FKP Authentication System

A. Pre-processing

In preprocessing the input image is converted into grayscale image. The median filter is used to improve the intensity of the pixels, reduce the noise and preserve edges. Median filter traverses the image pixel by pixel and each pixel value is replaced by median value of the neighboring pixels. The intensity of each pixel in an image is used to rank the neighbouring pixel. The contrast of the image is not reduced across steps since the neighborhood value do not shift boundaries and therefore it is not affected by outliers.

B. Feature Extraction

Feature extraction is the next step after preprocessing which extract the relevant inforamtion from the input image. Feature extraction is a technique which is used to extract the features from the biometric image. The extracted features are stored in the form of the feature vector. The features provide the discriminant information of the extracted ROI sub-image. In the proposed method, the Gabor filter is used to extract the local orientation features from the finger knuckle print. The k-Nearest Neighbor (kNN) is used in classifying the finger knuckle images in user identifcation.

1) Gabor Filter

Gabor filter is an efficient texture-based feature extraction technique. The object recognition, image content analysis etc uses the concept of Gabor feature extraction. The parameters used in gabor filter are, frequencies, orientations and smooth parameters of the Gaussian envelope[10]. Among the phase, magnitude and orientation features, orientation features are the most prominent and distinctive feature extracted by Gabor filter. Gabor filter formula is given in Equation (1) ,

$$G(x,y,\omega,\theta) = \frac{\omega}{\sqrt{2}\,\pi k} e^{\frac{-\omega^2}{8k^2}(4x'^2 + y'^2)} \left[e^{iwx'} - e^{\frac{-k^2}{2}} \right] \quad (1)$$

$$where\ x^1 = (x - x0)\boldsymbol{cos\theta} + (y - y0)\boldsymbol{sin\theta}$$

$$y^1 = (x - x0)\boldsymbol{sin\theta} + (y - y0)\boldsymbol{cos\theta}$$

In Equation (1), (x 0, y0) - the center of the function

ω is the radial frequency in radians per unit length.

θ is the orientation of the Gabor function in radians,

$$k = \sqrt{2} ln\,2\left(\frac{2^\delta + 1}{2^\delta - 1}\right),$$

δ is half amplitude bandwidth of the frequency

$\omega = \frac{k}{\sigma}$ where σ is the standard deviation of the gaussian envelope.

The parameters represented in the Gabor filter *G* extract the orientation and magnitude information of finger knuckle images.

C.Finger Knuckle Print Matching

1) K-Nearest Neighbor Classification

K-Nearest Neighbor's algorithm is used in pattern recognition for both classification and regression. KNN is a non-parametric model which is not characterized by a fixed set of parameters. The classification of an object is based on the majority vote of its neighbor. K is a positive integer. If k is 1, the object is assigned to a single nearest neighbor of the class which it belongs. The advantage of using the KNN is robust to noisy data and effective if the training data is large. A distance function needs to compare the example similarities. The distance is calculated using one of the following measures *i*) Euclidean distance, *ii*) Minkowski distance and *iii*) Mahalanobis distance. The Euclidean distance is used to calculate the distance function to find out the similarities between the pixels. The steps are given below to measure the distance similarities between the pixels in an images as in .

Algorithm: Euclidean distance

Input: T, the set of training objects, the test object, Z, which is a vector of attribute values, and L, the set of classes used to label the objects.

$c_z \epsilon\ L$, *the class of Z*

Output:

for each object $y \epsilon T$ do

Compute $d(z,y)$, the distance between z and y;

End

{

Select $N \subseteq$ T, the ser (neighborhood) of K closest training objects for z;

$c_{z=}\ argmax\left(\Sigma_{y\epsilon N} I(v = class\,(c_y)\right);$

Where, I is an indicator function which returns Boolean value 1, if its arguments is true and 0 otherwise

}

IV. Experiments and Results

Dataset

IIT Delhi finger knuckle dataset and Ploy u dataset are used to experiment the performance of the proposed system and the detail description of the two datasets which are used for the experiment are given below. The proposed system is entirely implemented in Matlab.

1) IIT Delhi dataset

The IIT Delhi database consists of 158 user's finger Knuckle images and for each person, 5 images are captured using the normal digital camera. The .bmp image files are used and image resolution is 80 x 100 pixels. For this experiment analysis, the images for segregated as 474 for training and 316 for testing.

2) PolyU dataset

The PolyU dataset finger Knuckle images are taken in low cost and low resolution camera in a peg free environment. The PolyU dataset consists f 165 user's finger knuckle images and the resolution of the images is 160 x180 pixels. Here the FKP images are in .jpg extensions. Here, 495 images used as training samples and 330 images are used as testing samples.

3) Experiment

The experiment conducted using the benchmark datasets. The Genuine Acceptance Rate (GAR) is one of the performance metrics used in evaluation of the finger knuckle personal authentication which is calculated by the total number of genuine matches against the number of matches performed by the system. Another parameter used for evaluation is Equal Error Rate (EER). A number of false acceptance rate and false rejection rate are used to calculate the Equal Error Rate. The normalized distance between the genuine and The decidability threshold is used to calculate the normalized distance between the genuine and imposter matching score [8] and the formula is

$$DT = \frac{\mu_g - \mu_i}{\sqrt{\sigma_g - \sigma_i}} - (2)$$

In equation 2, where μ_g is the mean value of genuine match score and μ_i is the mean value of imposter matching scores respectively.

σ_g and σ_i are standard deviation values of genuine and imposter matching scores respectively.

Additionally, the statistical measures such as sensitivity and specificity are measured. The sensitivity measures the proportion of authorized person correctly identified and the specificity measures the proportion of unauthorized person are correctly identified. The sensitivity and specificity are calculated by the given formula,

$$Sensivity = \frac{TP}{TP + FN} \quad (3)$$

In equation 3, where True Positive (TP) is correctly identified and False Negative (TP) is incorrectly rejected FKP images.

$$Specificity = \frac{TN}{TN + FP} \quad (4)$$

In equation 4, where True Negative (TN) is correctly rejected and False Positive (FP) is incorrectly identified FKP images.

4) Performance of feature extraction technique based on texture analysis

The personal authentication using finger Knuckle surface based on local features provides the promising result. The experiment is conducted in the IIT Delhi dataset and PolyU dataset and the performance metrics is calculated based on Equal Error Rate (EER), False Acceptance Rate (FAR) and sensitivity, specificity and Genuine Accept Rate (GAR). The experiment is conducted on the index finger is described in Table 1 respectively. The performance analysis chart is given in Figure 3.

TABLE 1. TEXTURE ANALYSIS BASED ON PERFORMANCE METRICS

Feature Extraction method	Dataset	Training samples	Testing Images	Index finger Knuckle				
				EER (%)	FAR (%)	Specificity (%)	Sensitivity (%)	GAR (%)
Gabor Filter	IIT Delhi	474	316	0.18	0.1	83.14	82.2785	82.2785
	PolyU	495	330	0.10	0.001	99.4	99.97	99.97

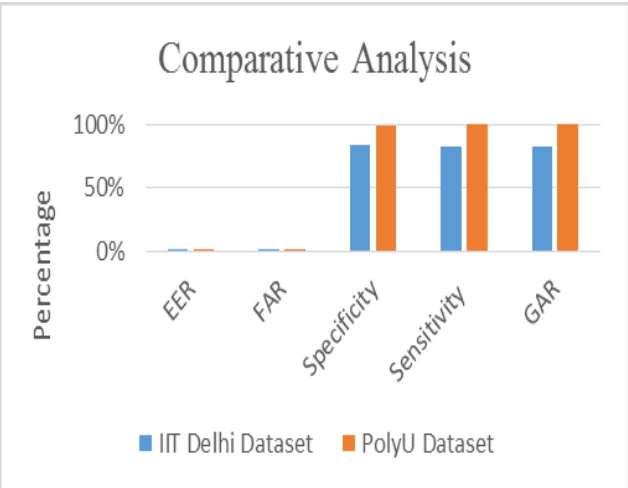

Fig. 3. Comparative Analysis Chart

5) Computational time analysis of proposed finger Knuckle authentication technique

Matlab is used to implement the proposed methodology and is executed in the system configuration of Intel Core i3 CPU with 2.00 GHz processor, 8 GB RAM. The time taken for computation for extracting features using a Gabor filter and classifying using the classifier Knn are evaluated and is illustrated in the Table 1.

The proposed approach extracts the features from the right index finger's proximal knuckle and matching using the classifier. The total computational time for extracting and matching the features in our proposed personal authentication techniques is 0.919 seconds which is fast enough to implement in real time scenario.

TABLE 1. ANALYSIS OF AUTHENTICATION TECHNIQUE BASED ON COMPUTATIONAL TIME

Key processing steps	Time (ms)
Image Capturing and loading	89
Preprocessing	180
Extraction and matching of Texture features	650

V. CONCLUSION

In this paper, finger knuckle is used for personal identification. The experiment is done on the IIT Delhi dataset and PolyU dataset to evaluate the performance of the finger knuckle identification system. Various advantages of using the finger knuckle for identification are highly rich in texture, low-resolution camera for capturing the image, size of the image is small, contactless and high degree of user acceptance rate. The feature extraction and classification technique used in this work is effective and achieves the accuracy of 85.133% for IIT Delhi dataset and 99.8 % for PolyU dataset. The finger knuckle biometric trait has a great future to use in real-time applications. This work can be extended by considering multiple finger knuckles and also distal region of the finger knuckle for identification and authentication.

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