Hybrid Approaches To Person Verification Using Fingerprint

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ABSTRACT: Different statistical methods for fingerprint verification have been proposed in recent years and different research groups have reported contradictory results when comparing them.

In this work, Fingerprint Recognition based on Eigen Space method is adopted. The original fingerprint images are transformed into a small set of feature space, called “eigen finger”, which are the eigen vectors of the training set and can represent the principle components of a typical finger prints. Then, the Eigen finger features are extracted by projecting a new fingerprint image into the subspace spanned by the “eigen finger”, and applied to fingerprint recognition with a Euclidean distance classifier. Experimental results illustrate the effectiveness of the method in terms of the recognition rate.

The proposed solution of the fingerprint recognition is based on the fingerprint authentication algorithms - Principal Component Analysis, Independent Component Analysis 1, Independent Component Analysis 2, Fisher’s Linear Discriminator and Gabor transform using fingerprint Images.

The goal of this work is to present comparative study of hybrid approaches of five most popular subspace-based fingerprint verification algorithms (PCA, ICA-1, ICA-2, FLD and Gabor transformation). The motivation was the lack of direct and detailed independent comparison in all possible algorithm implementations. It will be shown that no particular hybrid approach is the optimal and the choice of appropriate hybrid approach can only be made for a specific task.

Keywords: PCA(Principal component analysis), ICA **(**Independent Component Analysis**)**, FLD(Fisher's Linear Discriminant), Eigen space, and Gabor.

Introduction: Automatic fingerprint recognition has become a widely used technology in both forensic and biometrics applications. Despite a history of a thousand years during which fingerprints have been used as individual’s proof of identity and decades of research on automated systems, reliable and fully automatic fingerprint recognition is still an unsolved challenging research problem.

Internet and World Wide Web has changed the world into a global village, as a result of which we are enjoying lot of benefits of the virtual world. For example, we no longer have to stay in the queue to do our bank transactions or we need not personally visit a store to buy something. While this has made life much simpler, it has also created problems in various aspects which were not even dreamt of in the pre-Internet world.

One among the many problems is "Identity Fraud" which is becoming a serious threat to the entire world in terms of security. This is turning into a major cause of concern as all online transactions rely upon the user id’s and passwords and anybody who possess it can carry out the entire transaction easily. It is very easy to hack the user ids and passwords without the knowledge of the genuine user or sometimes the user himself may share the password and user ids to his friends or relatives. This is a drawback when security is concerned. The system does not know whether the user is genuine or not.

To overcome this problem, Biometrics can be treated as a feasible and universal alternative approach to the existing authentication methods. Many algorithms on biometrics have been proposed, using features of Individuals. In many cases they have yielded impressive performance. Still it’s not fool proof. To enhance the levels of security and reliability and also to improve the performance of the biometric systems, combinations of algorithms (hybrid approach) or combinations of features (multi modal) are used.

The focus of this work is on hybrid approach using Eigen space algorithms like PCA, ICA-1, ICA-2, FLD and Gabor transformation. From the previous work it is observed that an independent algorithm may not provide the necessary result. To get an improved performance over existing independent algorithmic approach we have followed a different approach. In this work combination of algorithms in all possible different ways are considered to make a hybrid biometric system, which is considered as an improvement over existing detailed independent comparisons in all possible algorithms.

Introduction to the Algorithms

Different statistical methods or algorithms for fingerprint verification have been proposed in recent years and different research groups have reported contradictory results when comparing the algorithms.

Principal Component Analysis

Principal component analysis (PCA) is a basis of modern data analysis - a black box that is widely used. Principal Component Analysis has been called one of the most valuable results from applied linear algebra. PCA is used abundantly in all form of analysis from neuroscience to computer graphics. It is a simple, non-parametric method of extracting relevant information from data sets.

Principal component analysis (PCA) is a vector space transform often used to reduce multidimensional data sets to lower dimensions for analysis. Principal Components Analysis is a method that reduces data dimensionality by performing a covariance analysis between factors.

PCA is a successful feature detection method for pattern recognition. It is the optimal dimension compression technique based on second-order information, in the sense of mean-square error. It deals with image vector whose dimension is usually high.

The main advantage of PCA is that the data is compressed by reducing the number of dimensions, without much loss of information.

Principal Component Analysis is a way of identifying patterns in data, and expressing the data in such a way as to highlight their similarities and differences. Since patterns in data can be hard to find in data of high dimension, where the luxury of graphical representation is not available, PCA is a powerful tool for analyzing data. The other main advantage of PCA is that once you have found these patterns in the data, and you compress the data, i.e. by reducing the number of dimensions, without much loss of information[11].

Objectives of Principal Component Analysis

- To discover or to reduce the dimensionality of the data set.
- To identify new meaningful underlying variables.

Mathematical background on Principal Component Analysis

The mathematical technique used in PCA is called Eigen analysis: we solve for the Eigen values and Eigen vectors of a square symmetric matrix with sums of squares and cross products. The Eigen vector associated with the largest Eigen value has the same direction as the first principal component. The eigenvector associated with the second largest Eigen value determines the direction of the second principal component. The sum of the Eigen values equals the trace of the square matrix and the maximum number of Eigen vectors equals the number of rows or columns of this matrix.

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Independent Component Analysis – I

ICA-I is a technique that extracts statistically independent signals from mixed signals. An ICA based finger print recognition method assumes that a finger image can be represented by a linear combination of statistically independent sources. It is well known that ICA better represents a variety of data distributions than. Thus, ICA techniques have popularly been applied lately to the problem of finger print recognition, especially for finger recognition[6].

Independent Component Analysis - II

The technique independent component analysis –II is used to estimate the independent characterization of human hand vectors (palms, fingers, or thumbs). It is known that there is a correlation or dependency between different human hand vectors. Finding the independent basic vectors that form those correlated ones is a very important task. The set of human hand vectors is represented as a data matrix *X* where each row corresponds to a different human hand. The correlation between rows of matrix *X* can be represented as the rows of a mixing matrix *A*. The independent basic vectors are represented as rows of source matrix *S*.

The ICA algorithm extracts these independent vectors from a set of dependent ones using when the dimension of the image is high, both the computation and storage complexity grow dramatically. Thus, the idea of using a real time process becomes very efficient in order to compute the principal independent components for observations arriving sequentially. Each eigenvector or principal component will be updated, using ICA algorithm, to a non-Gaussian component. If the source matrix *S* contains Gaussian uncorrelated elements then the resulting elements in the mixed matrix *X* will be also Gaussian but correlated elements[6].

Fisher's Linear Discriminant Analysis

PCA finds the most accurate data representation in a **lower** dimensional space and projects data in the directions of maximum variance as shown below. However the directions of maximum variance may be useless for classification. Thus we need to find projection to a line such that samples from different classes are well separated. This can be made possible using **Fisher Linear Discriminant**. Fisher Linear Discriminant project to a line which preserves direction useful for data classification. Fisher's linear discriminant is a classification method that projects high-dimensional data onto a line and performs classification in this one-dimensional space. The projection maximizes the distance between the means of the two classes while minimizing the variance within each class. This defines the Fisher criterion, which is maximized over all linear projections, *w*:

$$J(w) = \frac{|m_1 - m_2|^2}{s_1^2 + s_2^2}$$

where *m* represents a mean, s^2 represents a variance, and the subscripts denote the two classes. In signal theory, this criterion is also known as the signal-to-interference ratio. Maximizing this criterion yields a closed form solution that involves the inverse of a covariance-like matrix. This method has strong parallels to linear perceptrons[9].

Gabor filter method

Gabor filters have gained much attention for different aspects of computer vision and pattern recognition. Some successful applications include texture segmentation and texture feature extraction. Gabor filters are efficient in reducing image redundancy and robust to noise. Such filters can be either convolved with the whole image or applied to a limited range of positions. In such a case, a region around a pixel is described by the responses of a set of Gabor filters of different frequencies and orientations, all centered at that pixel position. Gabor proved that a signal's specificity in time and frequency is fundamentally limited by a lower bound on the product of its bandwidth and duration, and from this he derived the uncertainty principle for information (Gabor, 1946).

Gabor's theory leads to the idea that a visual system should analyze visual information most economically by using pairs of perceptive fields of symmetrical and asymmetrical response profiles in order to achieve minimum uncertainty in both spatial localization and spatial frequency .In this we propose Gabor filters for extracting texture features needed to characterize images in a database.

Gabor filters are a traditional choice for obtaining localized frequency information. They offer the best simultaneous localization of spatial and frequency information. However they have two main limitations. The maximum bandwidth of a Gabor filter is limited to approximately one octave and Gabor filters are not optimal if one is seeking broad spectral information with maximal spatial localization[2].

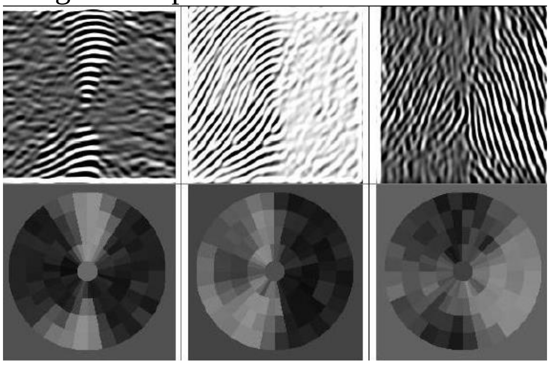


Figure a: Filtered images and their corresponding feature vectors for orientations 0°, 22.5° and 45° are shown.

Gabor filters optimally capture both local orientation and frequency information from a fingerprint image. By tuning a Gabor filter to specific frequency and direction, the local frequency and orientation information can be obtained as shown in Figure a. Thus, they are suited for extracting texture information from images. An even symmetric Gabor filter has the following general form in the spatial domain:

$$G(x, y\,;\, f, \theta) = \exp\left\{\frac{-1}{2}\left[\frac{x'^2}{\delta_{x'}^2} + \frac{y'^2}{\delta_{y'}^2}\right]\right\}\cos(2\pi f x')$$

$$x' = x \sin\theta + y \cos\theta$$

$$y' = x \cos\theta - y \sin\theta$$

where f is the frequency of the sinusoidal plane wave along the direction θ from the x-axis, and δ_x and δ_y are the space constants of the Gaussian envelope along x and y axes, respectively[14].

Experimental design

Data

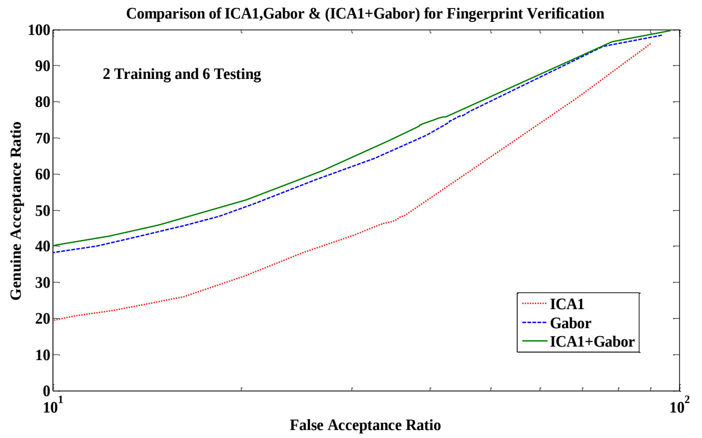
To measure the performance of the above described matching algorithms, we have tested the system on FVC2000 DB3. This database consists of 800 fingerprint images (100 distinct fingers, 8 impressions each). All images in the data set are of size 448x478 captured using Optical Sensor technology with resolution 500 dpi[10].

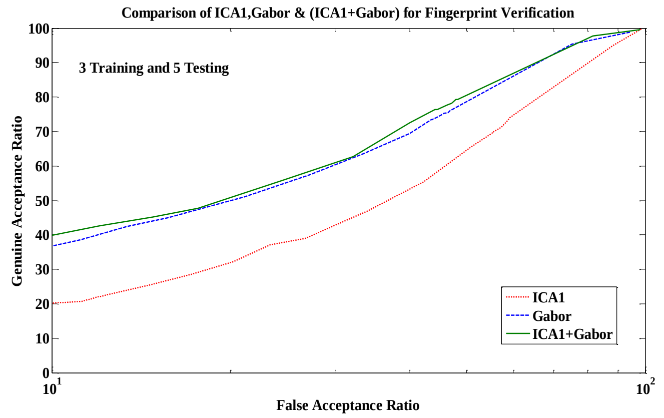
In this work the five algorithms PCA, ICA 1, ICA 2, FLD and Gabor filter are implemented on the above mentioned data set using MATLAB. Each algorithm was implemented with five different combinations of training and testing images. The different combinations of training and testing images to observe results were

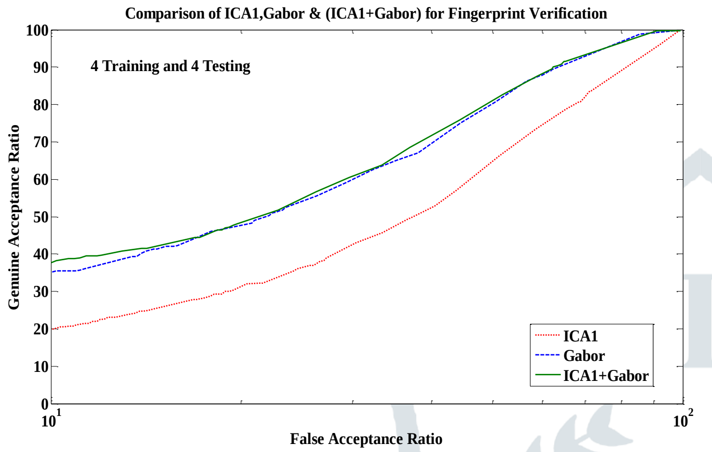
Trial 1:2 training images and 6 testing images
Trial 2:3 training images and 5 testing images
Trial 3:4 training images and 4 testing images
Trial 4:5 training images and 3 testing images
Trial 5:6 training images and 2 testing images

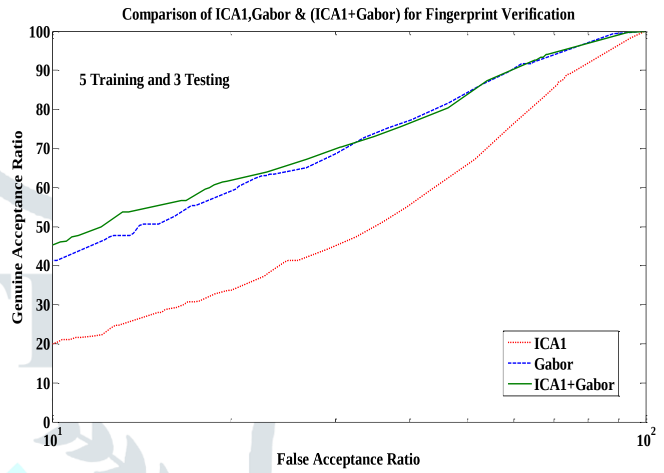
In each trial the algorithms PCA, ICA 1,ICA 2 and FLD is compared independently with Gabor filter and also the respective algorithm is fused again with Gabor filter using weighted sum rule to analyze the combined performance. The performance of the system is analyzed using Receiver Operator Characteristics (ROC), by plotting False Acceptance Ratio on X-axis and Genuine Acceptance Ratio on Y-axis.

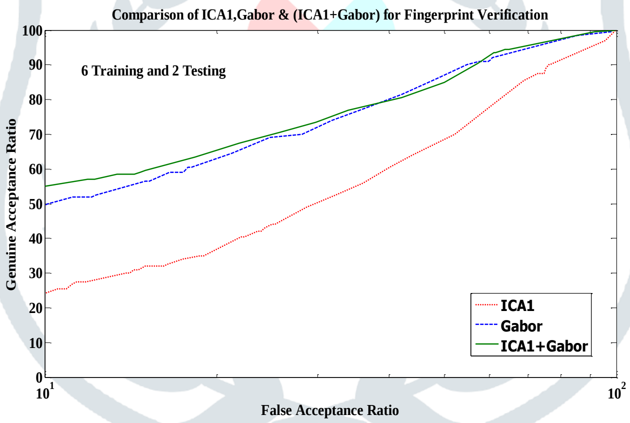
Among the trials **ICA 1 + Gabor** performs better than all other independent and hybrid methods in all training and testing images on the finger print database as shown in the graph.











Conclusion

In today's world, biometrics system is used almost everywhere for the security and personal recognition. The fingerprint is one of the most reliable physiological characteristics that can be used to distinguish between individuals.

This work introduces the person verification using finger print based on Principal Components Analysis, Independent Component Analysis-1, Independent Analysis-2, Fisher's Linear Discriminant method and Gabor transform method.

The finger print authentication system extracts the Eigen vectors of Eigen finger print from the trained and tested finger print and seeks the Euclidean distance by integrating the database for finger print recognition.

The goal of this work is to present comparative study of hybrid approaches of above mentioned five most popular subspace-based fingerprint verification algorithms in completely equal working conditions.

General conclusions

- The accuracy of a particular algorithm depends not only depends on data set but also depends on different training data sets. Viz ,when the training data set is small PCA out perform LDA and also PCA is less sensitive to different training data sets.
- Biometric data based approaches are now inevitable for Data Security and to operate System (Entry into workspace, Financial Transaction, etc.) in a secure manner.

- While some algorithms are moderately good and some are excellent, the real challenge is in finding reliable, non intrusive and low cost implementation of such methods.
- It is clear that the role of algorithms can play an important role. The actual matter is to find simple, reliable method that can be implemented in a low complexity hardware and sensor system.

Specific Conclusions

We have investigated an important class of Subspace (Eigen Space) Algorithms, wiz; PCA, ICA-1,ICA-2, FLD and Gabor transform for the problem of Finger Print based person Identification.

Table 1 : Algorithm performance of different metrics.

Algorithm	Genuine Acceptance Ratio for different cases of training and testing images				
	2Test-6Train	3Test-5Train	4Test-4Train	5Test-3Train	6Test-2Train
PCA	10	9.5	10	10.5*	10
ICA 1	19.5	20	20	20	24.5*
ICA 2	12.5*	10	10	10	10
FLD	13*	11	13*	12	12.5
Gabor	39	38	36	42	50*
PCA + Gabor	38	37	34.5	42	47*
ICA 1 + Gabor	**40**	**40**	**38.5**	**46**	**56***
ICA 2 + Gabor	37.5	36.5	35.5	40	43*
FLD + Gabor	38	38.25	35.9	42.5	49*

The best algorithm-metric combinations are bolded.

*** indicates best result for a particular combination of training and testing.**

From the above algorithm-metric **Table 1** let us try to draw some conclusions based on the specific task:

- From the experiments performed on Finger print images, comparisons of Independent algorithms PCA, ICA I, ICA2, FLD, Gabor and comparisons of hybrid approaches PCA + Gabor, ICA 1 + Gabor, ICA 2 + Gabor and FLD + Gabor. **ICA 1 + Gabor** performs better than all other independent and hybrid methods in all training and testing images on the finger print database .
- The experimental results shows there are no significant performance differences between ICA architecture 2 , PCA and FLD. ICA architecture 1 performs better compare to standard PCA, ICA 2 and FLD. Gabor transform significantly outperforms the standard PCA, ICA 1, ICA 2 and FLD. It can be concluded that the performance of ICA strongly depends on its involved PCA process.
- Except for few cases best results are observed for 6 training and 2 testing images, thus, increased training for algorithm will improve the performance.

Future Work

- Future works will be emphasized on multimodal biometric, which is a better method than uni-modal biometric. For example multiple instances of a single biometric, such as 1, 2, or 10 fingerprints, 2 hands, and 2 eyes.
- We can also consider the combinations of features (finger print+ face, fingerprint+ palm print, finger print +speech etc;). The difficulty here is finding two or three “Best” combination of features among the 15 odd features that are available.
- Generally difficult is to assure clean data. Thus the choice of algorithms that work well on noisy data or improperly captured data needs to be investigated.
- A thorough investigation of many other subspace methods for finger print recognition is needed to ascertain the best among these.

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