Brief review of Iris Recognition Using Principal Component Analysis, Independent Component Analysis and Gabor Wavelet

Sarita G. Firake, Dr. Prof. P. M. Mahajan
Dept. of E &TC, J.T. Mahajan C.O.E, Faizpur, India

***Abstract*— Biometric authentication techniques aimed to identify individuals using fingerprints, face, iris, retina and palm prints. Among all these techniques, iris recognition is best one due to its high reliability, low error rate. An iris is colored part between pupil and white sclera such that it is well protected by the eyelid. The iris is internal body part which is externally visible and remains stable throughout life, don't change with age .Also remains protected from any external factors. An iris code is created by encoding visible texture of the iris using 2D Gabor wavelet (GW).It gives 256 byte iris code which is stored in database and used for future identification. Principal Component analysis (PCA), Independent component analysis (ICA)are the famous dimensionality reduction techniques guarantees minimum square error. In this paper we are taking brief review iris recognition using methods like PCA, ICA and Gabor wavelet.**

Keywords*— *Iris recognition system, Principle component analysis (PCA), Independent component analysis (ICA) ,Gabor wavelet(GW).

I. INTRODUCTION

Today the major requirement is in providing reliable, rapid means for automatic recognizing the identity of person. Comparing to other personal

Identification methods based on ID cards or password, iris is more advantageous as it shows huge variation of patterns between two persons. Even it is distinct from left eye to right eye of same person. Also

irises of twins are not alike. Biometric methods based on iris pattern have found more accurate and interesting recently. Some research work [8-12] has also shown the iris remains stable from one year of age over lifetime, don't change with age. Iris image is captured using non contact imaging device which is important in practical application.

Irides can be used to identify individual, not just confirm their identity. So high reliability [1-4, 8], non invasiveness, anti falsification, stability, uniqueness

have made iris recognition promising way to provide security in application like passenger Control in airport, border control, financial service, important data access. The iris of an eye is considered as optical fingerprint for personal identification as every iris has high details with unique texture. It creates distinctive fingerprint that can be imaged at some distance from the person.

Image processing algorithms can be used to extract the unique patterns of iris from an eye image and encode it into an iris template. This iris template contains mathematical representation of the unique information stored in the iris and allows comparisons to be made between templates. Daugman [5]first proposed iris recognition algorithm based on iris codes .Algorithm found to be more accurate requires less than one second for iris identification. Similarly Wildes[6] used first derivative of image intensity to find location of edges of iris. An iris has epigenetic information which is formed from individual DNA such that finally developed randomly. Some properties of iris that enhances its suitability for automatic detection are as follows:

- Protection from external environment as it resides internally.
- Impossible to surgically modify as it leads to have risk of vision.
- Its physical response to light.
- Its intrinsic polar geometry which provide natural co-ordinate system and origin.

This paper is organized as follows. Introduction is followed by Iris recognition system in detail. Then feature extraction techniques like PCA, ICA, and GW are studied relative to iris recognition system. Based on this some results are discussed and finally concluded with method giving highest recognition rate.

II. IRIS RECOGNITION SYSTEM

Many researcher have worked on iris recognition and human iris recognition is divided into 4 main tasks which are localization and segmentation, normalization, feature extraction and coding, matching.

A. Localization

It consists of discerning iris texture (isolating actual iris) from other texture of captured image by detecting inner pupil and outer sclera boundaries. Well known methods such as Integro-differential, Hough transform are used to detect boundaries includes canny edge detection to generate an edge map. Gradients were biased in vertical direction for outer iris boundary. Vertical and horizontal gradients were weighted equally for inner iris boundary as suggested in [8].

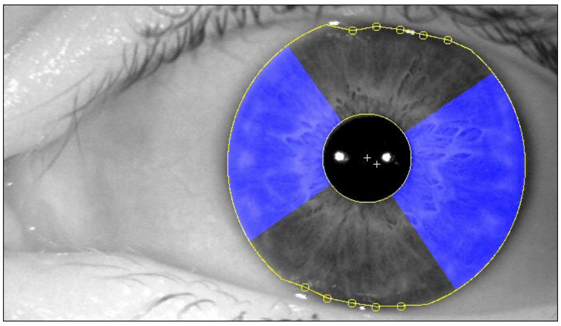


Figure 1: Example of captured iris image with automatically localized iris and marked region of interest.

Eyelids are isolated by putting line to upper and lower eyelid parts using linear Hough transform. Other horizontal line is then drawn which intersects with the first line at the iris edge that is closest to the pupil; the second horizontal line allows maximum isolation of
eyelid regions while a thresholding operation is used to isolate eyelashes.In iris recognition, iris location is major step spending much processing time.

B. *Normalization*

Normalization means to prepare segmented iris image for feature extraction process. They are based on polar to Cartesian transformation unwrapping iris textures into fixed size rectangular blocks. It is done with the help of Daugman's Rubber sheet model.

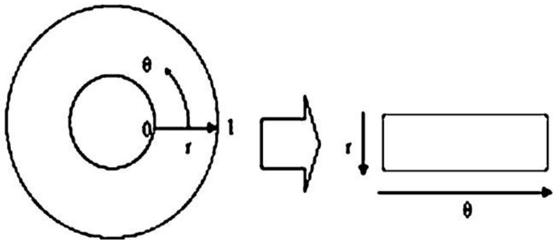


Figure 2 Daugman's Rubber sheet model.

Here centre of pupil is considered as reference point and remapping of iris image I(x, y) from raw Cartesian coordinates to polar scale (r,θ) as indicated in (1),

$$I(x(r,\theta), y(r,\theta)) \rightarrow I(r,\theta) \quad (1)$$

Where r is on interval [0, 1] and θ is angle [0,2Π] with (2),(3),

$$x(r,\theta)=(1-r)x_P(\theta)+rx_I(\theta) \quad (2)$$

$$y(r,\theta)=(1-r)y_P(\theta)+ry_I(\theta) \quad (3)$$

Where x_P, y_P, x_I and y_I are the coordinates of the pupil and iris boundaries along the direction θ.

Iris from different people maybe captured in different size maybe due to illumination variations, changes in camera to eye distance. Such deformation in iris texture may affect matching result. This problem solved by Wildes [6] as he register input image with model image. Normalization minimizes distortion of iris caused due to pupil movement and simplifies further processing.

C. *Feature extraction*

Feature extraction is main step of any iris recognition system where iris provides abundant texture information. Here actually input data get processed to extract key feature and given as input to matching, next step. A feature vector consists of ordered sequence of features extracted from various iris images. Daugman [5]developed iris feature extraction based on 2D Gabor filter such that repeated image captures produced iris on same location having the same resolution.

But this restricts to apply practically Boles[7] used zero crossing representation such that it is tolerant to illumination variation.They first localized and normalized the iris by using edge detection. The zero-crossings of the wavelet transform are then calculated at various resolution levels over concentric circles on the iris. The resulting one dimensional (1D) signals are then compared with the model features using different dissimilarity function. The algorithm is invariant to translation, rotation, scale and illumination and can handle the noisy conditions as well.According to [26] Lim et al. used 2D Haar wavelet transform to extract features from iris image. By quantizing feature vector iris image is represented.

Iris data constitute very high dimensional space. To reduce excessive dimensionality of scanned data so as to make recognition algorithm viable subspace techniques like PCA, ICA are widely used. Feature vectors are extracted and classified according to hamming distance, dissimilarity function, and weight vector.

D. *Matching*

In matching step, decision is made about person who claims particular identity (identification is done by comparing features with that of database).Here feature vectors are classified according to various thresholding methods like Hamming distance, dissimilarity function.

John G. Daugman [5,10] done iris recognition with 2D Gabor wavelet transform using 2D Gabor filters to extract a feature vector from given iris image. Filtering of iris images gives 1024 complex phasor showing phase structure of iris at various scales .The phasors, filter output is quantized to generate 2048 bits iris code describing iris. The variation between a pair of iris codes was measured by their hamming distance with the help of EX-OR operation, so gives rapid results.

Wildes[6.8] have representation of iris texture with four different resolution levels and used normalization correlation to identify image class. Boles and Boashash [7] done zero crossing representation of 1D wavelet transform with various resolution levels showing iris texture and used method of iris representation based on Euclidean distance and Hamming distance. Consistency of iris images from the same eye found using correlation filters by Kumar [25].

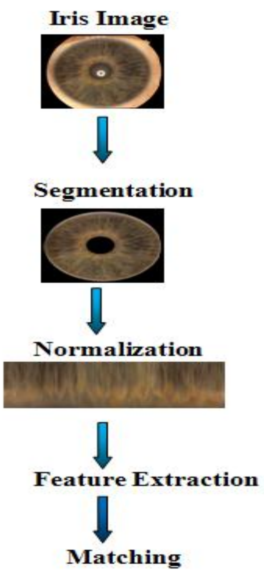


Figure3: Iris recognition system

Figure 3 shows general flow of iris recognition system.

III. PCA TECHNIQUES

Increased usage of images over internet leads to demand of more space and hence it is necessary dimension reduction techniques. One of such required technique is PCA which guarantees minimum mean square error but needs transformation of images in form of m rows, n columns into vectors .PCA used to identify patterns in data and mark their similarities and differences makes an easy way to analyze data and extract iris features.PCA was invented in 1901 by Karl Pearson and depending on application sometimes also known as Karhunen-Loeve transform (KL T) or Hotelling transform.

PCA involves eigenvalue calculation of covariance data matrix. Turk et al.[22] done PCA based on eigenface techniques, as algorithms used Eigen vectors for representing main components of face. Xingfu Zhang [23] done PCA as preprocessing procedure to remove redundant data reserving useful data. Then run algorithm for ICA .He named this algorithm 2D PCA based ICA.2D PCA is improved over PCA as it deletes vectorization steps. Hammed Ranjzad [24]used improved feature vectors using filter banks .They have locally applied PCA and ICA on extracted feature of iris images from filter banks output. Their results have shown improved iris recognition with less false match rate in matching step.

PCA is used to reduce length of feature vector which takes the data points constructing lower dimensional linear subspace showing best description of variation of data points from their mean. In PCA, feature vectors of input images are extracted using following steps:

1. Get data of irises.
2. Subtract the mean from each data dimension. Mean is average across each dimension.
3. Calculate covariance matrix.
4. Calculate eigenvectors and eigenvalues of covariance matrix.
5. Choose principle components that we want to keep in our data and form feature vector.
6. Derive new data set.

IV. ICA TECHNIQUES

Iris data obtained from ROI of iris images requires high dimensional space. The subspace techniques reduces this dimensionality of iris data so that iris recognition algorithm can be run easily .Mostly used subspace projection techniques is Independent Component analysis (ICA) which projects the data from high dimensional space into lower dimensional space.ICA is generalization of PCA which decorrelates the higher order statistics.

ICA is statistical computational technique for the subspace analysis used for automatic identification of underlying hidden factors. It has been successfully applied to data analysis; signal processing, early vision system.ICA technique is used to decompose complex dataset into independent sub parts to apply in data analysis , blind source separation.

Aapo[14]have computed ICA basis images for their work using FastICA algorithm whereas M.S.Bartlett[15]have done ICA by following Infomax algorithm also Maximum Likelihood approach[16]for the same.

ICA finds linear decomposition of observed data into statically independent components .Suppose

$$x = As \qquad (4)$$

Where x is vector of observed signal, A is scalar matrix of mixing coefficients is vector of source signal.ICA finds separating matrix W such that

$$y = Wx = Was \qquad (5)$$

where y is vector of independent components.ICA looks linear representation that minimizes an objective function.

Many ICA algorithms simplify procedure by whitening data which means to remove any correlations in data.ie make uncorrelated or independent signals. Simply means treating all components equally before running algorithm. So as dimensions are reduced, computations required also minimized.

The Iris is structure shows great amount of texture information.ICA captures local crucial information from the iris to create set of compact features. Iris after pre processing known as iris vector which belongs to iris space. Aim of ICA is form iris space such that it gives better description of irises.

Generally ICA cannot identify correct ordering, actual number and scaling of source signals.ICA is important to blind signal separation and has many application.

ICA captures higher order statistics and projects input images from training set to basis vectors such that they are independent[26].ICA requires simultaneously recorded mixtures as the same number of components such that each mixture is combination of independent components.

V. GABOR WAVELET

Wavelet transform can perform multi-resolution analysis, i.e. different time-frequency resolution pair with the help of its tunable kernel size. This property makes the wavelet transform suitable for edge detection, filter design, image object recognition, image compression[12].Among kinds of wavelet transform, Gabor wavelet transform has good biological and mathematical properties. Also it can be used with either continuous or discrete input signal.

Gabor wavelets were first proposed by Gabor in1946 as joint time frequency analysis tool for 1 D signal decomposition. As they observed its best resolution in time and frequency domain, they were extended to 2D domain in 1978.Daugman first observed similarity between shape of 2D GW and receptive field of human visual system[5, 10].An effective method for extracting textural information from iris requires computation of 2D Gabor phasor coefficients. This concept was proposed by Daugman in1980.Feature extraction using GW involves 2 steps: 1.Convolve the image with the set of GW each tuned to certain frequency, orientation and bandwidth.2. Fuse the response of GW to get local feature vector. So GW has been used as powerful tool for texture segmentation, face recognition.

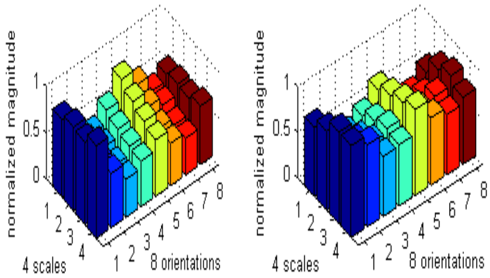
There is always uncertainty between time and frequency resolution of the window function as when time duration gets larger, the bandwidth becomes smaller. Among all window function, Gabor function is proved to achieve lower bound with best resolution in joint domain.

GW performs well for feature extraction, for retrieving image data, for reducing feature dimension without affecting performance.GW exhibits characteristics of capturing visual properties spatial localization, orientation and frequency selectivity.GW features have amazing results in texture analysis, image segmentation, machine vision, recognition, tracking[12]. Wing-Pong[12]proposed new method for feature extraction based on integral image also have shown simplified version of GW with efficient feature computation such that these SGW can replace GW for real time application. They have included fast algorithm for feature extraction with their computational complexity. They also compared performance between SGW and GW. Finally they got results showing feature extraction with SGW is more efficient than GW, as SGW used FFT for computation whereas Shen [13]proposed maximum responded GW for measuring registration quality of registered images.

Manjunath[17]used GW for browsing ,retrieval of image data and their results showed that GW performs well as compared to traditional Pyramid-structured wavelet transform(PWT),three structured wavelet transform(TWT),multi-resolution simultaneous auto regressive model(MR-SAR).They used adaptive filter selection for dimension reduction without degrading performance. Arvazhagan [18] proposed method for rotation invariant texture classification using GW in which features are found by calculating mean, varience of Gabor filtered images.

Wei-lun Chao[19] show an example of using GW feature for image retrieval. Figure (a) is query image,(b) is image from database,(c),(d) are their corresponding GW feature. In first two images, sky portion is similar, so colour information is used to compute image similarity. Using GW, features between two images are similar and expected retrieval results achieved.

(a) (b)



(c) (d)

Figure 4 : Features extracted from images based on 4*8 GW set. Image (a)is used as query,(b) as database image and it is clear that query feature of (c) is similar to (d) showing correct retrieval result.

VI. RESULTS FROM DISCUSSION

JIN-XIN SHI[20]compared feature extraction algorithm based on PCA, ICA,GW for compact iris code. They used these three methods to generate optimal basis elements which represent iris signals efficiently. The coefficients of these methods are used as feature vectors .Then iris feature vectors are encoded into the iris code for storing and comparing individual's iris pattern. Iris coding is done to designate a set of local iris features to form a compact image representation. The comparison is done between two 256 byte iris codes. The iris encodings are compared by computing Hamming distance between them.

They used pictures from database CASIA [21]iris database. They employed usual iris recognition method along with Euclidean distance calculation.

Hamming distance between an iris code A and iris code B is sum of disagreeing bits (sum of EX-OR between) divided by N, which is total number of bits in the pattern.

$$HD = 1/N \sum_{j=1}^{N} \mathrm{Aj} + \mathrm{Bj} \qquad (6)$$

Where N=2048(256*8)

If two patterns are derived from same iris, Hamming distance between them will be close to 0 due to high correlation.

They obtained recognition rate as given below,

Table 1: Comparison of algorithms

2D GW	PCA	ICA
94%	89.5%	92.2%

From results obtained above, they finally concluded that 2DGW have highest recognition rate. This is so, as iris is rotator and 2D GW have rotation invariance, but they leads to complex computations so more processing time[20].

VII. CONCLUSION

In this paper, we have studied iris recognition methods using three techniques PCA, ICA, 2D GW. To meet current security requirement, one of the biometric authentication method, i.e. iris recognition systems have found to be more accurate, compact, and efficient with satisfactory results because of rich texture of iris region and great variation of pattern among individuals.

REFERENCES

[1] A. Jain, R.Bolle, and S.Pankanti,Eds.,*Biometrics:Personal Identification in aNetworkedsociety.*Norwell, MA; Kluwer, 1999.
[2] D.Zhang,*Automated biometrics: Technologies and Systems.* Norwell MA: Kluwer, 2000.
[3] T.Mansfield,G.Kelly, D. Chandler, and J. Kane,"biometric product testing final report,"Nat.Physical Lab.,U.K.,2001
[4] F.Adler, *Physiology of the eye: Clinical Application*, 4thEd. London, U.K.:C.V.Mosby Co., 1965.
[5] J.Daugman,"High confidence visual recognition of persons by a test of stastical independence, "*IEEE Trans. Pattern Analy.MachineIntell*., vol. 15, pp.1148-1161, Nov.1993.
[6] R.Wildes,J. Asmuth,G.Green,S. Hsu, R. Kolezynski, J. Matey, and S. Mebride,"A machine vision system for iris recognition,"*Mach.vis.Applic*.,vol.9,pp.1-8,1996.
[7] W.boles and B.Boashash,"A human identification technique using images of the iris and wavelet transform,"*IEEETrans.Signal Processing*, vol. 46, pp.1185-1188, Apr.1998
[8] R.wildes,"Iris recognition: an emerging biometric technology,"Proc.IEEE, vol.85, pp.1348-1363, Sept, 1997.
[9] L.Flom and A. Safir,"Iris recognition system,"U.S.Patent 4641394, 1987.
[10] J.Daugman,"Biometric personal identification system based on iris analysis,"U.S.Patent 5 291 560, 1994
[11] R.Wildes, J.Asmuth, S.Hsu, R.Kolezynski, J.Matey, and s.Mcbride,"Automated, noninvavasive iris recognition system and method," U.S. Patent 5 572 596,1996
[12] Wing-Pong Choi, Siu-Hong Tse, Kwok-Wai Wong ,Kin –Man Lam,"Simplified Gabor Wavelets for human face recognition"Science direct,vol.41,pp.1186-1199,2008.
[13] Linlin Shen, Li Bai,"3D Gabor Wavelets for evaluating SPM normalization", Science Direct, vol.12, pp375-383,2008.
[14] Aapo Hyvarinen and ErkiOja, "Independent component analysis:atutorial," http://www.cis.hut.fi/~aapo/papers/IJCNN99_tutorialweb/, 1999.
[15] M. S. Bartlett, J. R. Movellan, and T. J. Sejnowski, "Face Recognition by Independent Component Analysis," *IEEE Trans. Neural Networks*, vol. 13, no. 6, pp. 1450-1464, 2002.
[16] A. Hyvärinen, "The Fixed-point Algorithm and Maximum Likelihood Estimation for Independent Component Analysis," *Neural Processing Letters*, vol. 10, pp. 1-5, 1999.
[17] B. S. Manjunath and W. Y. Ma, "Texture features for browsing and retrieval of image data," *IEEE Trans. Pattern Analysis and Machine Intelligence*, 18(8): 837-842, 1996
[18] S. Arivazhagan, L. Ganesan, and S. P. Priyal, "Texture classification using Gabor wavelets based rotation invariant features," *Pattern recognition letters*, 27(16): 1976-1982, 2006
[19] Wei-lun Chao," Gabor wavelet transform and its application", R98942073.
[20] JIN-XIN SHI, XIAO-FENG GU." The Comparison of Iris Recognition Using Principal Component Analysis,Independent Component Analysis and Gabor Wavelets" 978-1-4244-5540-9/10/ ©2010 IEEE
[21] Institute of Automation Chinese Academy of Sciences. Database of CASIA iris image [EB/OL].
[22] Turk M. and Pentland A., "Eigenfaces for recognition". Journal ofCognitive Neuroscience, 3, 72–86, 1991.
[23] Xingfu Zhang, Xiang min Ren "Two Dimensional Principal Component Analysis Based Independent Component Analysis for Face Recognition" 978-1-61284-774-0/11/ ©2011 IEEE
[24] Hamed Ranjzad, Afshin Ebrahimi, Hussein Ebrahim nezhad Sadigh,"Improving Feature Vectors for Iris Recognition through Design and Implementation of New Filter bank and locally compound using of PCA and ICA"
[25] A. Kumar, A. Passi, Comparison and combination of iris matchers for reliablepersonal authentication, Pattern Recognition 43 (2010) 1016–1026.
[26] Imen Bouraoui and Salim Chitroub, Ahmed Bouridane," Performance Evaluation of Independent Component Analysis in an Iris Recognition System"