A COST-EFFECTIVE IRIS RECOGNITION SYSTEM USING LINEAR DISCRIMINANT ANALYSIS AND CROSS-CORRELATION TECHNIQUES

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Abstract: Authorization and identification has become a vital part of security systems of any society. With the changing of technology implementations in the present scenario, every country specially developing countries like India needs a cost-effective and reliable solution for authentication system. In this paper, efficient technique for iris recognition system is described which provides a reliable authentication at low cost. The proposed system uses linear discriminant analysis and cross correlation methods for identification and verification purpose. The system was implemented and tested using a dataset of 80 samples of iris with different contrast quality. The classification rate compared with the well-known methods is also discussed.

1 INTRODUCTION

Biometric is automated methods of identifying a person or verifying the identity of a person based on a physiological or behavioral characteristic (Eric J. Lerner, Feb 2000)(K. L. Kroeker, 2002)(S. Liu et al., 2002). Examples of physiological characteristics are fingerprint, hand geometry, facial characteristics and iris recognition. Behavioral characteristics include traits that are learned or acquired. Dynamic signature verification, speaker verification etc. are examples of behavioral characteristics.

In any pattern recognition system, the main issue is the relation between inter-class and intra-class variability. For example in face recognition the difficulty is that the face is changeable organ. It displays a number of expressions and it varies with viewing angle, pose and age. it has been proved that for facial recognition the images taken a year apart, the best algorithms have error rates of 43% (Phillips 2000) to 50% (Pentland 2000). The inter-class variability is limited because different faces possess the same basic set of features. For these reasons iris patterns become a good alternative approach to reliable visual recognition (K. L. Kroeker, 2002) of persons. The iris has the great mathematical advantage that its pattern variability among different persons is enormous. As an internal organ of the eye, the iris is well protected from environment and stable over time. The iris begins to form in the third month of gestation and the structure creating its pattern are complete by the eighth month. Its complex pattern can contain many distinctive features such as arching ligaments, ridges, furrows, crypts, rings, corona, freckles and a zigzag collarette. The density of melanin pigment determines Iris color. Blue irises resulting from an absence of pigment. The properties of the iris that enhance its suitability for use in biometric identification include:

- Protected from the external environment
- Impossibility of surgically modifying without the risk of vision

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- Physiological response to light
- Ease of registering its image at some distance

2 IRIS FEATURE AND PROCESS

There are verities of features that can be used to distinguish one iris from another. One of the main characteristics is the trabecular meshwork, a tissue which gives the appearance of dividing the iris in a radial fashion that is permanently formed by the eighth month of gestation. During the development of iris there is no genetic influence on it, a process known as chaotic morphogenesis that occurs during the seventh month of gestation, for which identical twins have four different irises. The iris is protected behind the eyelid and cornea unlike other biometrics such as fingerprints or face, the chances of damage is minimal or nil. The iris is not a subject to be change with age, it means its pattern remain stable till death. Generally, the process of iris recognition system includes the following steps:

- Image Acquisition
- Iris Localization
- Image Optimization
- Comparison

The image of iris can be captured using a standard camera using both visible and infrared light and may be either a manual or automated procedure. In manual procedure, the user needs to adjust the camera to get the iris in focus and needs proper user training to be successful. The automated process uses a set of cameras that locate the face and iris automatically. Once the camera has located the eye, the image is thenanalyzed to identify the outer boundary of the iris, the pupillary boundary and the center of pupil. This information is used to produce a vector record called iriscode. This record is then stored into a database for future comparison.

3 RELATED WORK

Daugman's work: the visible texture of a person's iris in a real-time video image is encoded into a compact sequence of multi-scale quadrature 2-D Gabor wavelet coefficients, whose most-significant bits comprise a 256-byte iris code (J. Daugman, "How Iris Recognition Works")(J. Daugman, Nov 1993)(J. Daugman, Dec 2001).

Wildes' work: is very similar to the above-mentioned method. A laplacian pyramid is used to apply a 2-D transformation. A match value is calculated for the four bands through spatial correlation (R. Wildes, Sept 1997).

Boles' work: based on calculating the zero-crossings representations of the wavelet transform. These representations are stored as templates and are used for the matching algorithm (W. Boles, 1997).

4 THE PROPOSED SYSTEM

This system is divided into these parts:

A. Image Acquisition: This is the stage of acquiring the eye image using digital camera.

B. Iris Localization: Finding the boundary between the pupil and the iris, the outer boundary of iris and the center of the pupil.

C. Polar Transformation: Using the center and the radius we find a polar coordinate system. In this system the feature of the iris is extracted.

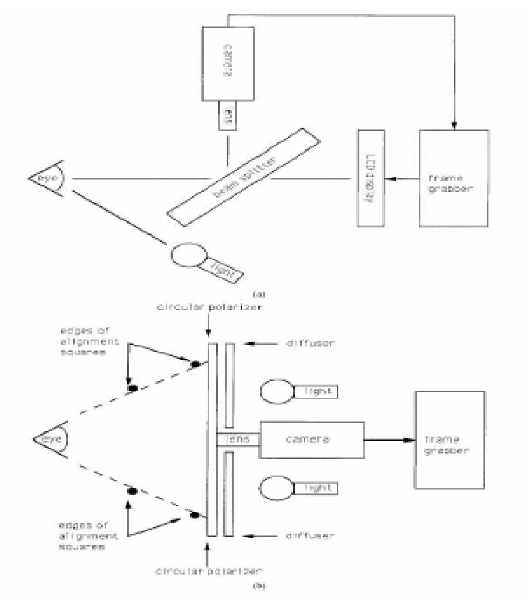
D. Identification: Using linear discriminant analysis we found a match for the acquired iris feature.

E. Verification: Using cross correlation method it verifies the identified image to get efficient search result.

A. Image Acquisition

The iris is a relatively small (1 cm diameter), dark object and that human operator are very sensitive about their eyes, this matter requires careful engineering. The following points should be concern:

- Describe to acquire images of the iris with sufficient resolution and sharpness to support recognition
- It is important to have good contrast in the interior iris pattern without resorting to a level of Illumination that annoys the operator
- The image should be well framed (i.e. centered)
- Noises in the acquired images should be eliminated as much as possible



B. Iris Localization

Since the value of the pixels in the pupil not always be zero so we need an edge detection algorithm (M. Turhan, Apr 1999) to make all values of the pupil to be zero to easy determination of the pupil center and then get the pupil boundary. Get the center of the pupil by counting the number of black pixels of each column and row. Then get each row and column that has maximum number of pixels. Then determine the center as:

Get the position of first and last pixels (X_a, Y_a) and (X_b, Y_b) of this row. Find the center $X_0 = (X_a + X_b) / 2$. Similarly apply same step to find $Y_0 = (Y_a + Y_b) / 2$. Consequently, the radius of the virtual circle of the pupil can be determined. A similar procedure is extended to locate the outer boundary that can be apparent by using the mid-point algorithms of circle.

C. Polar Transformation

The image should be transformed into polar coordinate system. The q(q Î[0;2p]) parameter and dimensionless *p (p Î[0;1])* parameter describe the polar coordinate system. Thus the following equations implement:

I(x(p, q), y(p, q)) à I(p, q)

Where,

$x(p, q) = (1-p)*x_p(q) + p*x_i(q)$

$y(p, q) = (1-p)*y_p(q) + p*y_i(q)$

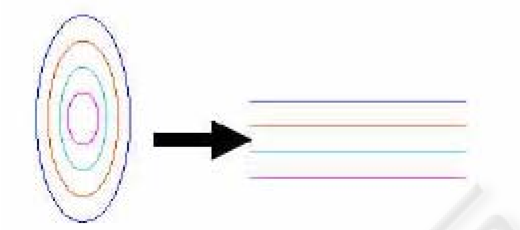
$x_p(q) = x_{p0}(q) + r_p*cosq$

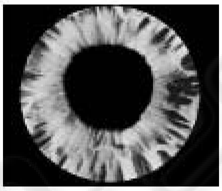
$y_p(q) = y_{p0}(q) + r_p*sinq$

$x_i(q) = x_{i0}(q) + r_i*cosq$

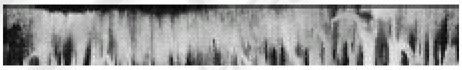
$y_i(q) = y_{i0}(q) + r_i*sinq$

Where r_p and r_i are respectively the radius of the pupil and the iris. Figure-4 shows how iris image is converted to polar coordinates.





iris region



unwrapped image after transformation

D. Identification

Linear Discriminant Analysis (LDA), is perhaps the best known technique for classifying an observation of unknown class membership into one of two populations on the basis of predictors. It happens frequently in literatures that "classification" and "discrimination" are used interchangeably, though the former is used sometimes when the problem is one of "clustering" (P. N. Belhumeur et al, Jul 1997)(J. Buckheit et al.).

Given *C* groups or classes $\{X_1, X_2, ... , X_c\}$ contains *N* sample images $\{x_1, x_2, ... , x_n\}$ such that each image belongs to exactly one of the *C* classes. If the total scatter matrix S_T is defined as:

$$S_T = \sum_{k-1}^{N} (X_k - \mu)(X_k - \mu)_T$$

Where *n* is the number of sample images, and m Î R_n is the mean image of all samples, then after applying the linear transformation W_T, the scatter of the transformed feature vectors $\{y_1, y_2, ... , y_n\}$ is $W_T S_T W$. In PCA, the projection W_{opt} is chosen to maximize the determinant of the total scatter matrix of the projected samples, i.e.,

$$W_{opt} = \arg\max |W_T S_T W| = [W_1 W_2 ... W_m]$$

Where $\{W_i \mid i = 1, 2, ..., m\}$ is the set of n-dimensional eigen-vectors of S_T corresponding to the m largest eigenvalues.

Linear Discriminant Analysis (LDA) is an example of a class specific method, in the sense that it tries to "shape" the scatter in order to make it more reliable for classification. This method selects W in such a way that the ratio of the between-class scatter and the within-class scatter is maximized. Let the between-class scatter matrix be defined as

$$S_B = \sum_{i=1}^{c} N_i (\mu_i - \mu)(\mu_i - \mu)^T$$

and the within-class scatter matrix be defined as

$$S_W = \sum_{i=1}^{c} \sum_{X_k \in X_i} N_i (X_k - \mu_i)(X_k - \mu_i)^T$$

Where m_i is the mean image of class X_i, and N_i is the number of samples in class X_i. If S_W is nonsingular, the optimal projection W_{opt} is chosen as the matrix with orthonormal columns, which maximizes the ratio of the determinant of the between-class scatter matrix of the projected samples to the determinant of the within-class scatter matrix of the projected samples, i.e.,

$$W_{opt} = \arg\max \frac{|W^T S_B W|}{|W^T S_W W|}$$

where $\{W_i \mid i = 1, 2, ... , m\}$ is the set of generalized eigen-vectors of S_B and S_W corresponding to the m largest generalized eigenvalues $\{l_i \mid i = 1, 2, ... , m\}$ i.e., $S_B W_i = \lambda_i S_W W_i$ i = 1, 2, ... , m

Note that there are at most $C - 1$ nonzero generalized eigen-values, and so an upper bound on m is $C - 1$, where C is the number of classes. The solution is given by the min($C - 1$) eigen-vectors (called "canonical variates" by Rao) of $S_W^{-1} S_B$.

E. Verification

Once the iris was identified the system verifies it using cross correlation technique to produce better search results.

Given two images 1 and 2, image-1 is the template image and image-2 is the image to be searched

$$\rho = \frac{\sum_x \sum_y (g_1(x, y) - \mu_1)(g_2(x, y) - \mu_2)}{\sqrt{\sum_x \sum_y (g_1(x, y) - \mu_1)^2 \sum_x \sum_y (g_2(x, y) - \mu_2)^2}}$$

$-1 \leq \rho \leq 1$

where,

$g_1(x, y)$ = individual gray values of template matrix

μ_1 = average gray value of template matrix

$g_2(x, y)$ = individual gray values of search matrix

μ_2 = average gray value of search matrix

5 RESULTS

To show the effectiveness of the proposed system, in our implementation, we used 10 classes each contain 5-9 iris images acquired under different conditions. The images were collected as gray-scale images. For each iris class, we randomly choose four samples for training and the rest for testing. In identification tests, an average correct classification rate of 98.97% is achieved. These tests were performed on 300 MHz uniprocessor Pentium based system.

Operating states of our previous system.

FAR (%)	FRR (%)
0.01	6.9
0.05	4.2
0.1	3.6
1.0	1.8

Operating states of system using LDA.

FAR (%)	FRR (%)
0.01	3.1
0.05	1.8
0.1	1.1
1.0	0.07

Operating states of the proposed system.

FAR (%)	FRR (%)
0.01	2.7
0.05	1.3
0.1	0.8
1.0	0.03

Comparison with Existing Methods

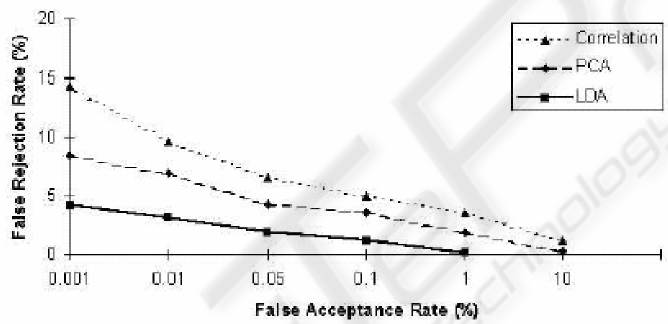
Daugman documented first iris recognition system in 1993 (J. Daugman, Nov 1993). This system is based on wavelet transformation. It is implemented on a RISC general-purpose CPU and 32X32 array of 74F86 ICs. Wildes described a system for personal verification based on automatic iris recognition in 1996 (R. Wildes, Sept 1997). This system used a very similar technique like Daugman's. It was implemented on Sun SPARCstation 20 and written in UNIX C Shell languages without optimization. Boles proposed a system using zero-crossing representation (W. Boles, 1997). Our early works was based on correlation method and PCA. All these algorithms are based on gray image. A gray iris image can provide enough information to identify different individuals. The methods proposed by Daugman and Wildes are the best among all, but these methods require expensive hardware like RISC & parallel processing architecture systems to implement it. The proposed system can run on uniprocessor system. So we can say that this proposed system is very much cost-effective between these methods.

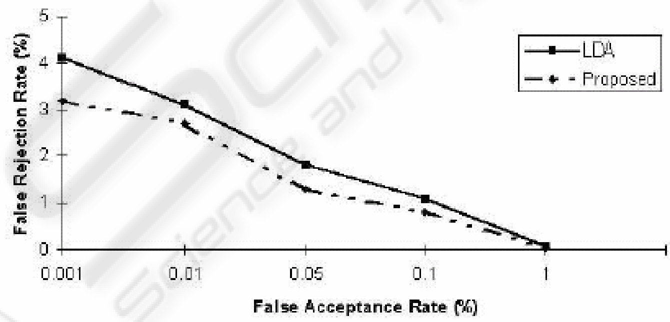
6 CONCLUSION

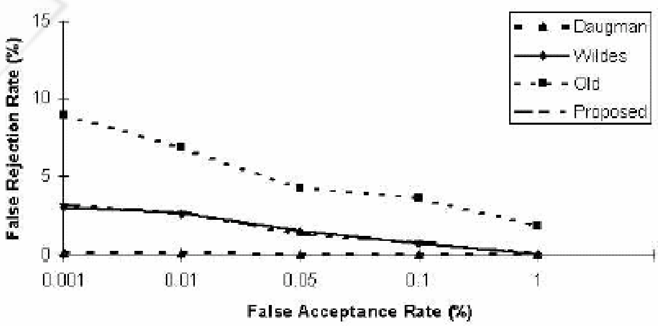
In this paper, we have presented a new and effective algorithm for iris recognition. The proposed system uses linear discriminant analysis for identification then verifies the result using cross-correlation. Experimental results have shown that the proposed algorithm achieves high performance at low cost. Developing countries like India where population density and crime rates are increasing day by day, such high technology oriented authentication systems are desperately in requirement. The existing iris recognition systems require high cost computing system, which is not feasible for developing countries. The proposed system is highly suitable for such countries and can be used for a wide range of application areas involving forensic science, crime search, driver's license, passport, etc.

Some efficient techniques are used in this proposed method, these are:

- A computer graphics algorithm for detecting the center of the pupil and localizing the iris area.
- Transforming the localized iris area into a simple coordinate system.
- Identification process based on LDA.







Cost comparison of systems

Technique	System Requirement	Approximate cost ($)
Daugman's	RISC general-purpose CPU and 32X32 array of 74F86 Ics, Standard CCD video camera, 330mm lens, LED illuminator	25,000 – 40,000
Wildes'	Sun SPARCstation 20, Low light CCD camera, 80mm lens, diffuse polarized illuminator	14,000 – 20,000
Proposed	Pentium uniprocessor based PC, General CCD camera, 50mm lens, 50W halogen illuminator	2,500 – 7,000

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