Iris Recognition Using Localized Zernike's Feature and SVM

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Abstract: *Iris recognition is an approach that identifies people based on unique patterns within the region surrounding the pupil of the eye. Rotation, scale and translation invariant, are very important in image recognition. Some approaches of rotation invariant features have been introduced. Zernike Moments (ZMs) are the most widely used family of orthogonal moments due to their extra property of being invariant to an arbitrary rotation of the images. These moment invariants have been successfully used in the pattern recognition. For designing a high accuracy recognition system, a new and accurate way for feature extraction is inevitable. In order to have an accurate algorithm, after image segmentation, ZMs were used for feature extraction. After feature extraction, a classifier is needed; Support Vector Machine (SVM) can serve as a good classifier. For the N-class problem in iris classification, SVM applies N two-class machines. Indeed, in this type of validation, data are divided into K subsets. At any given moment, one is for testing and the other one is exclusively for validation. This method is called K-fold cross validation (Leave one out) and each subset is considered as an original series. Simulation stage was accomplished with IIT database and the comparison between of this method and some other methods, shows a high recognition rate of 98.61% on this database.*

Keywords: *Biometrics, iris recognition, zernike, K-Fold, SVM.*

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1. Introduction

Biometric systems are among new identification system. In the field of biometrics, it has been shown that iris recognition systems have high level of accuracy since the iris is a unique pattern of people. In recent years, with the spread of information technology, the biometric systems have been popped up. Researchers were looking for new methods to be easily measured and do not change over time. These major features that used for identification are physical and behavioural traits.

Physical traits include finger prints, iris patterns, face and hand geometry and etc., behavioural traits include voice, signature and etc., However, physical traits have been proven to be more beneficial as they accurately identify each individual and distinguish one from another.

Iris recognition is one of the most important biometric recognition approaches in human identification.

Daugman was the first researchers who work on iris [5, 6]. Daugman system is the most successful system and the rights are now owned by the Iridian Technologies.

Wildes *et al*. [19, 20] uses the Gauss-Laplace filter to decompose the iris image and carries on the correlation comparison for the corresponding images, the computation is huge. Boles and Boashash [3] proposed a novel iris recognition algorithm based on zero-crossing detection of the wavelet transform.

Zhonghua and Bibo [21] proposed a new method, based on the optimized Gabor filters.

Lim, Noh and other researcher proposed different recognition algorithms.

In our article, after image pre-processing that has contained image enhancement, segmentation and normalization, features extraction and template matching accomplish.

Template matching compares the user template with database's templates.

Today, most of researchers used many types of algorithms for image classification. For example, neural networks, hamming distance and etc.

Zernike Moments (ZMs) are not invariant with respect to scale and translation. ZMs extract spatial information from an image. The features are in complex form and are represented by their phase and magnitude [11, 17, 18].

In this system, the iris template code is converted to ZMs in a feature vector and this vector used as an input to a Support Vector Machines (SVM) system. SVMs are a popular machine learning method for classification, regression and other learning tasks [20].

An SVM classifies data by finding the best hyperplane that separates all data points of one class from those of the other class. Iris recognition system has 4 stages as shown in Figure 1:

1. Image Acquisition.
2. Iris Detection Includes Iris Localization, Segmentation and Normalization.

3. Feature Extraction.
4. Classification.

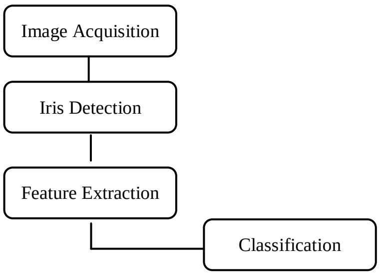

Figure 1. Basic structure of an iris recognition system

2. Iris Detection

In iris recognition system, accurate iris segmentation is so important and is a crucial step.

An eye image contains some parts, such as: The pupil, eyelids, sclera and so on and for the iris recognition, this is necessary to remove unused parts and detect iris region.

If the iris region is not correctly segmented in the recognition system, the eyelash, eyelid and some another noise would affect on the normalized iris pattern [4, 7].

In the first stage of this project, isolation of the iris region in human eye is primary task. The iris region can be shown by two circles, one between iris and sclera boundary and another is between iris and pupil. The eyelids and eyelashes occlude the upper and lower parts of iris ring.

Hough transform is used for determine the circle and line's parameters.

An edge map is generated by calculating the first derivatives of intensity values in an eye image and then threshold the result as shown in Figure 2.

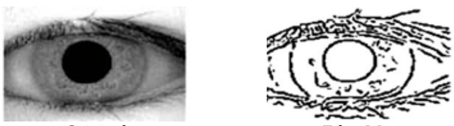

Figure 2. Original image and its edge map.

Canny edge detection is used to create the edge map and then for enhance contrast of bright and dark region, adjusting image gamma applied to the image and after that, it is necessary to perform thresholding.

Hough transform is used again for returning the coordinates of top and bottom eyelid. Canny filter and thresholding are used for this step as shown in Figure 3.

With the Hough transform, the centre and radius of pupil and iris will be afforded. For eyelids isolating, the linear Hough transform is used [13].

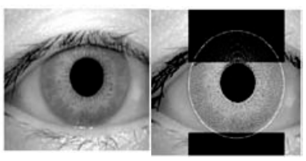

Figure 3. Iris segmentation.

3. Iris Normalization

Because different irises have different sizes and the size of the irises from the same eye may be different and the iris and the pupil are non concentric, therefore may affect the advantage of iris matching. In order to avoid these factors and achieve more accurate recognition, the normalization of iris images is implemented.

In normalization, the iris circular region is transformed to a rectangular region so that it has fixed dimensions in order to allow comparisons.

Normalization of the iris region performs by unwrapping circular region into a rectangular block of constant dimensions.

In normalization step, we map the detected iris from (x, y) Cartesian coordinates to the normalized non concentric polar coordinate.

For normalization of iris region a technique based on Daugman's rubber sheet model [13] is implemented.

The rubber sheet model takes into account pupil dilation and size inconsistencies in order to produce a normalized representation with constant dimensions as shown in Figure 4.

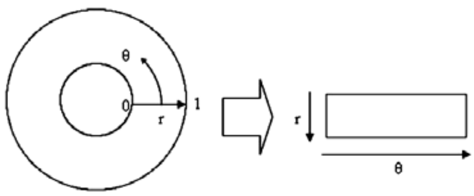

Figure 4. Daugman's rubber sheet model.

$$r' = \sqrt{\alpha}\beta \pm \sqrt{\alpha\beta^2 - \alpha - \gamma_I} \quad (1)$$

$$\alpha = o_x^2 + o_y^2 \quad (2)$$

$$\beta = \cos(\pi - arc(\frac{o_y}{o_x}) - \theta) \quad (3)$$

Where displacement of the centre of the pupil relative to the centre of the iris is given by o_x, o_y and r' is the distance between the edge of the pupil and edge of the iris at an angle, θ around the region and r_I is the radius of the iris [13].

The normalized pattern is created by backtracking to find the Cartesian coordinates of data points from the radial and angular positions in the normalized pattern as shown in Figure 5.

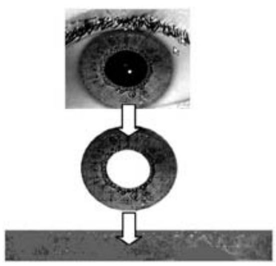

Figure 5. Original image, Iris and normalized iris.

4. Zernike Moments

ZMs are a class of orthogonal moments. It outperforms the others generally even though it is more complicated than the geometrical moment. For ZMs, Zernike introduced a set of complex polynomials which form a complete orthogonal set over the interior of the unit circle of $x_2+y_2= 1$. The Zernike polynomial can be used for reconstruction and recognition of shape. To compute the ZMs of a given image, the centre of the image is taken as the origin and the pixel coordinates are mapped to the range of the unit circle. Those pixels falling outside the unit circle are not used in the computation.

As it has already been mentioned, ZMs are the most widely used family of orthogonal moments due to their extra property of being invariant to an arbitrary rotation of the object that they describe. They are used, after making them invariant to scale and translation, as object descriptors in pattern recognition applications [16].

The advantages of considering orthogonal moments are that they are shift, rotation and scale invariant and very robust in the presence of noise. The invariant properties of moments are utilized as pattern sensitive features in classification and recognition applications [12].

However, the fact that moments are orthogonal is not their most important features. Any orthogonal polynomial could be used as a basis function from which easy reconstructions could be made. What makes ZMs valuable for the task of image classification is that they are rotationally invariant. Rotational invariance is achieved by computing the magnitudes of the ZMs [9].

The rotation of an image is easily expressed in polar coordinates since it is a simple change of angle.

The kernel of ZMs is a set of orthogonal Zernike polynomials defined over the polar coordinate space inside a unit circle. The complex ZMs of order n with repetition l of a function $f(r, \Theta)$ are defined as:

$$A_{nl} = \frac{n+1}{\pi}\int_0^{2\pi}\int_0^1 f\,(r,\theta) Z_{nl}^*(r,\theta) r dr d\theta \tag{4}$$

Where * denotes complex conjugate and the circular Zernike polynomials in a unit circle are defined as:

$$Z\,(r,\theta) = Z\,(r\cos(\theta), r\sin(\theta)) = R_{nl\,(r)} e^{il\theta} \tag{5}$$

The real-valued radial polynomials are given by:

$$R_{nl\,(r)} = \sum_{\alpha=0}^{\frac{n-|l|}{2}} (-1)^s \frac{(n-s)!}{s!(\frac{n+|l|}{2}-s)!(\frac{n-|l|}{2}-s)!} r^{n-2s} \tag{6}$$

Where l=-∞,-2,-1, 0, 1, 2, ∞; the integer $n \geq 0$, $|l| \leq n$ and n - |l| is always even.

The discrete approximation of the continuous Zernike integral based on Equations1 and 2 for image function $I(i, j)$ with spatial dimension $M\times N$ is written as follows:

$$A_{nl} = \frac{n+1}{\pi}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1} I\,(i,j) e^{-il\theta_{ij}} \tag{7}$$

Where the discrete polar coordinates:

$$r_{ij} = \sqrt{x_j^2 + y_j^2},\ \theta_{ij} = arctan(\frac{y_i}{x_j}) \tag{8}$$

ZMs have mathematical properties; make them ideal image features to be used as shape descriptors in shape classification problems. However, many factors need to be considered to apply ZMs correctly.

5. Feature Extraction

To prepare a unique and accurate feature code, the discriminated data that is hidden in iris pattern, should be mined.

ZMs are the mappings of an image onto a set of complex Zernike polynomials. Since, Zernike polynomials are orthogonal to each other, ZMs can represent the properties of an image with no redundancy or overlap of information between the moments. ZMs are significantly dependent on the scaling and translation of the object. Nevertheless, their magnitude is independent of the rotation angle of the object. Hence, we can utilize them to describe shape characteristics of the objects. For obtain ZMs, it's necessary to map the image into unitary circle, thereupon we divide the iris image into 20×20 region to have a quadrangle shape of image and then apply Zernike function to each region as shown in Figure 6.

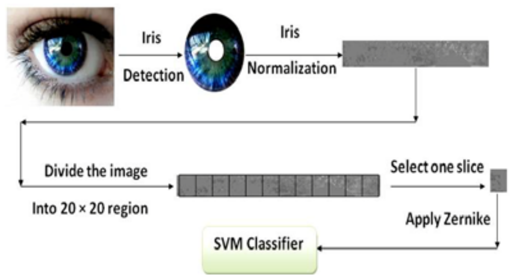

Figure 6. Basic Structure of this approach.

As it's explained above our proposed representation computes ZMs from 20×20 regions to capture the needed information. The normalized iris is 20×240. We divide the iris image into 20×20 regions (without any overlapping). The 1×49 vector from each region is computed. The image is divided to 12 regions. Hence, the feature vector for each image has 588 columns.

By increasing the order of ZMs, the recognition rate will be improved. We choose the ZMs order 12 and then apply to image.

6. SVM Classifier

In the field of pattern classification, there are a number of classifiers to choose from: Artificial neural networks, nearest neighbour and variations including k-nearest neighbour and weighted k-nearest neighbour.

However, the classifier that has gained popularity in recent years are the SVM classifier. SVM is a relatively new learning machine and work on the principle of structural risk minimization. A SVM is binary classifier that optimally separates the two classes of data. In first step, SVM determine the optimal hyperplane which will separate the two classes and in the next step non-linearly separable classification problem transform into linearly separable problem.

The objective of the SVM classifier is to separate data with a maxima margin and obtaining the maximal margin results in a better generalization of the data as shown in Figure 7.

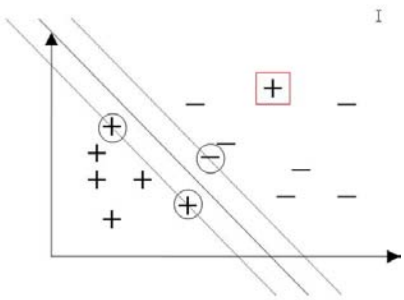

Figure 7. SVM principle.

We can use a SVM when our data has exactly two classes. An SVM classifies data by finding the best hyperplane that separates all data points of one class from those of the other class. The best hyperplane for an SVM means the one with the largest margin between the two classes. Margin means the maximal width of the slab parallel to the hyperplane that has no interior data points [8]. SVM simultaneously minimizes the classification error and maximizes the geometric margin.

7. Classification

In image classification, an image is classified according to its visual content. The feature vector consists of ZMs computed on the iris image that is divided to 12 regions. The final feature vector is a concatenation of these vectors.

We start by training a SVM classifier for images. The iris image of each person will be used as the positive and all of other iris of other persons in the database as the negative.

For the n-class problem in iris classification, SVM is used as n two-class machine. Indeed, in this type of validation, data are divided into *k* subsets. In each time, one is for testing and all another data are used exactly for validation.

K-fold cross validation is used in the field of machine learning to determine how accurately a learning algorithm will be able to predict data that it was not trained on.

When using the k-fold method, the training dataset is randomly partitioned into *k* groups. The learning algorithm is then trained *k* times, using all of the training set data points except those in the kth's group.

Leave-one-out cross validation is extremely useful. In general, if the correct value of k is used, *k*-fold cross validation provides the best estimate cross validation error.

Once the features vectors computed, we use SVM classifier with linear function kernel for determining which image belongs to which class. The SVM classifier is first trained using a set of training samples and then test the testing samples.

We use Matlab's standard function. Because SVM classify two classes, we define a loop that in first loop, first class is +1 and all another is 0, and in second loop, the second call is +1 and all another is 0.

8. Experimental

For testing this approach, Statistical results are presented based on IIT database [10]. This iris image database mainly consists of the iris images collected from the students and staff at IIT Delhi, India. This database has been acquired in the Biometrics Research Laboratory during January-July 2007 using JIRIS, JPC1000 and digital CMOS camera. The acquired images were saved in bitmap format. The resolution of these images is 320×240 pixels and all these images were acquired in the indoor environment.

100 images of the database were considered. The data was consisted of 100 classes and each class has 10 eyes. In each step we select 9 samples of each class for training and 1 sample for testing the algorithm.

In 100 stages we test the information and take average. The comparison between this method and other methods is listed in Table 1 [14, 15].

Table 1. Comparison between our methods and some other methods.

Approach	Recognition Rate
Daugman	98.58
Wildes	86.49
Masek	83.92
Our Method	98.61

FAR, FRR and ROC curve are used for fulfilment scale.

In Daugman method, to compute the False Accept Rate (FAR) and False Rejection Rate (FRR), because using of hamming distance for matching, it's necessary to set threshold.

The *FAR* is also known as a type 1 error [2]. It is computed by:

$$FAR = \frac{NFA}{NIVA} \tag{9}$$

Where *NFA* is the number of false acceptances. *NIVA* is the number of impostor verification attempts. The *FAR* is the measure of likelihood that the biometric security system would incorrectly accept an attempt by an unauthorized user to access the system. The FRR is also known as a type 2 error. It is computed by:

$$FRR = \frac{NFR}{NEVA} \quad (10)$$

Where, *NFR* is the number of false rejections. *NEVA* is the number of enrolee verification attempts. The *FRR* is the measure of likelihood that the biometric security system would incorrectly reject an attempt by an authorized user denying the access of the system.

ROC curve is a two-dimensional measure of classification performance. It can be understood as a plot of the probability of classifying correctly the positive examples against the rate of incorrectly classifying true negative examples. In this sense, one can interpret this curve as a comparison of the classifier across the entire range of class distributions and error costs. Usually, decision rule is performed by selecting a decision threshold which separates the positive and negative classes.

The ROC is a plot of the genuine acceptance rate against the false acceptance rate for all possible system-operating points (that is, the matching threshold) and it measures the overall performance of the system. Each point on the curve represents a particular decision threshold as shown in Figure 8.

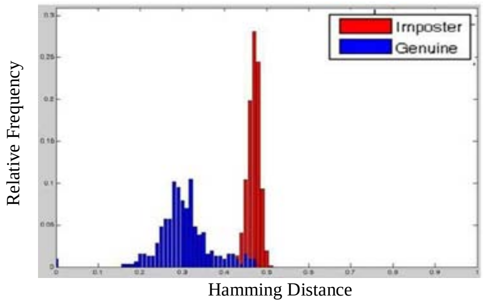

Figure 8. Hamming distance for authentic and imposters in daugman method.

In an ideal case, both the error rates that are the FAR and FRR should be zero and the imposter distribution should be disjointed.

We calculated FRR and FAR. FRR and FAR are respectively 2.7% and 0.02% and accuracy is 98.61%. The ideal ROC in such a case is a step function at zero FAR.

On the other hand, if the genuine and imposter distributions are exactly the same, then the ROC is a line segment with a slope of 45° with an end point at zero FAR.

ROC curves are an excellent way to compare several approaches and Figure 9 shows that our way has a good accuracy like daugman method.

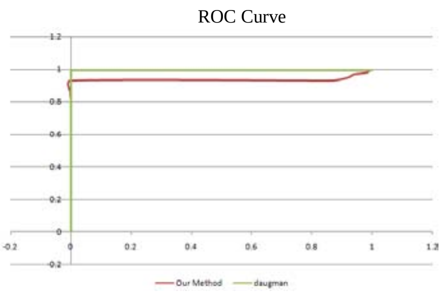

Figure 9. ROC curve in daugman method and our method.

9. Conclusions

In this study, we proposed a robust iris recognition system which uses ZMs to characterize iris texture. In first step, we use both canny edge detection and Hough circular transform for iris localization and noise detection and then, for feature extraction we utilize ZMs as feature extractor on the 12 divided parts of image with size 20×20 and then for each image we have one vector with size 1×588. Actually a ZM is a very powerful operator for describing the characteristics of the iris texture image. Finally, a SVM Classifier is used for classification as one of the neural network approach. Our system is tested on the IIT database and the comparative study shows that our system has a recognition rate (98.61%) compared with other methods. Next step is to save some image and calculation parameters in the source database to reduce the processing time of the system with the large number of people and find other methods with high response time and better accuracy.

10. Future Works

While the most common use of iris recognition to date is physical access control in private enterprise and government, the versatility of the technology will lead to its growing use in large sectors of the economy such as transportation, healthcare and national identification programs. Although, security is clearly a prime concern, iris recognition is also being adopted for productivity-enhancing applications like time and attendance. Current face recognition [1] and iris recognition technology relies on the person to stand in front of a Camera, Scanner and line up the eye properly Now, researchers try to capture iris recognition at a distance. Some of counterintelligence Agency in the world is developing technology that will be able to identify people from their iris, even they are moving. But differences in simple factors like lighting and expression can impede identification. Iris recognition technology is more reliable than face recognition technology but its limitation is that it requires a person who will stand in front of the camera or scanner and we're looking at remote iris recognition. It would be more valuable if the iris could be capture by a camera while the person moves at a distance and this is our ambition.

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