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Identification Based on Iris Geometric Features

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ABSTRACT

Biometric based authentication system aims to reconstruct the existing token based system. As there is a great need for secured identification in the current information era, it is achieved by biometric features. Iris based recognition system even though is one of the youngest biometric trait for human identification has received a larger impact. Among the various biometric traits, iris has the richest set of information which can be used for human identification. Iris consists of several features such as color, texture feature, macro features and geometric features. In this study, we propose to extract the geometric features based on the pupil, collarette and iris which are used for recognition. This innovative methodology proposes the extraction of geometric information based on the radius, roundness, diameter, roughness, smoothness and other geometric structures of the iris. The results exhibit that these features are discriminating features for identification. This proposed methodology based on geometric features for identification has proven better identification results.

Key words: Iris, biometric, pupil, collarette, geometric features

INTRODUCTION

The conventional identification system is based on token and knowledge, such as key, password, magnetic tape and chips, etc. However, all of these can be embezzled, forgotten or forged and hence password and token-based recognition systems are nowadays supplanted by a biometric recognition system. Even in some systems where password and token are still used, on top of it a biometric layer is added for more secure authentication. Hence, there is a tremendous growth in biometric based identification system when compared to past decade. Biometric includes reference to the measurement, analysis, classification, science of personal recognition and verification or identification by using distinguishable biological (physiological) or behavioral trait, features or characteristic of that person. Biometric identification is the process of associating an identity of the input biometric data by comparing it against the enrolled identities in a database (Jain *et al*., 2004). Some of the commonly used physical or behavioral traits are: Face, fingerprint, palm print, hand geometry, iris, keystroke, signature, voice and gait. Apart from these, there are also some traits which are used to identify a person uniquely based on odour, tongue, ear, knuckle print.

Among the various biometric traits, 'Iris' is proved to be a predominant and popular biometric feature for authentication and identification with a high degree of accuracy and distinctiveness. It is also proved for its reliability and universality. The finger print has also received substantial concentration and is being effectively used in many applications over one hundred years. Face and speech have also been extensively studied over 25 years, whereas, 'Iris recognition' is a newly emerging trait in personal identification and is reported to be the most reliable biometric trait in identification and authentication (Daugman and Downing, 2001). For its biological development and the features present in the iris is proved to be unique and stable throughout the life time of the person (Wildes, 1997). The performance of the identification system depends more on the search space and the accuracy rate. Existing systems are till now small-scaled, databases and henceforth identifying an imposter is not a difficult task but as the size grows the unique identification becomes cumbersome.

MATERIALS AND METHODS

Anatomy of human eye and iris: The human eye is an asymmetrical globe which measures nearly an inch in diameter. The front view of the human eye (the part what we see) as shown in Fig. 1 includes:

- Pupil (center of the eye)
- Iris (the pigmented darker part)
- Cornea (a dome structure over the iris)
- Sclera (white part)
- Conjunctiva (layer of tissue covering the eye)

The lens is placed behind the iris and the pupil which is responsible for the focus of light at the back of the eye. Major part of the human eye is packed with vitreous which is a clear gel. The light passes to the back of the eye through the pupil and then to the lens. The retina is the group of sensing cells which converts the received light into electrical impulses. The impulses are carried to the brain by the optic nerves which are behind the eye. A small extra-sensitive area called the macula is present within the retina that gives central vision. It is positioned at the center of the retina and contains a small depression or pit, the fovea at the center of the macula that gives the clear sight. Parts of the eye and their functions are presented in Table 1.

Iris is a Greek word means goddess of the rainbow due to the many colors of the iris and hence the name. The iris is a thin circular ring region, a part of the human eye positioned between the black pupil and white sclera presenting a unique and rich texture information, such as patterns, rifts, colors, rings, spots, stripes, filaments, coronal, furrows, minutiae and recess and other detailed characteristics seen under the infrared light. The iris is composed of loosely woven soft tissues. The iris are responsible for the amount of light reaching the retina by controlling the diameter and size of the pupil which is hole a located in the center of the iris. The Iris is the only internal organ which seen from outside. Further, it is a measurable internal physical feature which is unique and cannot be easily altered due to ecological effects. The probability of finding any two eyes identical, are approximately 1 in 10^52. It has nearly about 250 points of identification for comparison. The minute iris patterns and textures which is the phenotypic feature are determined during the foetal development and not inherited from the gene and for this reason the right and left eye of a person are not alike and same even for the identical twins. It has been proved that the color of the eye and the appearance of the eye are genetically inherited (genotype) but the texture patterns are not inherited (epigenetic).

Table 1: Function of human eye

Part of eye	Functions
Aqueous humor, crystalline lens, vitreous humor	Refractors of light
Retina	Receiver of light
Choroid	Absorber of light
Iris	Regulator of light
Ciliary circle	Regulate to distance
Eyebrow, eyelid, eyelashes, apparatus for the tears	Protectors and cleansers

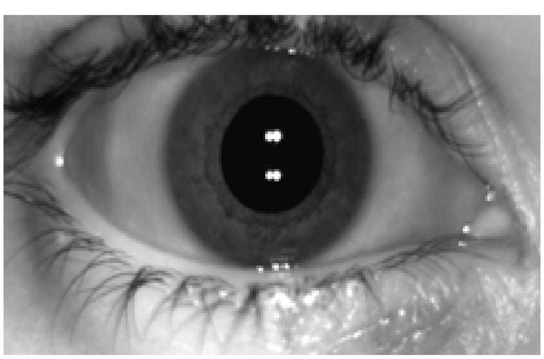

Fig. 1: Human eye

The color of the iris, can be green, blue, or brown. In some cases it can be hazel (a combination of light brown, green and gold), grey, violet or even pink. Although there are a variety of colors in the iris the dark pigment melanin is responsible for the ranges of colors in the iris. The amount of melanin is the deciding factor in the iris color. The color of the iris is brown or black which is due to the quantity of melanin when it is more. The red or yellow is because of pheomelanin caused by melanocytes which is found less in blue and green color iris. If it is a moderate quantity of melanin then it is hazel. In brown color iris the surface of the iris is smooth and is heavily pigmented. With Blue and hazel color iris the surface is irregular with crypts. The color of the eye may be influenced by more than 50 genes and hence the genetics of eye color are more complex than what they appear (Schwab, 2012).

Iris originates in the sixth week of gestation period. At end of the third month the ciliary fold are formed and by the completion of the fourth month the vascular layers of the iris is formed. During the fifth month the pupillary membrane, the iris stroma and sphincter muscle are formed. The development is completed by the end of eight month but the stroma layer is very thin, the cellular framework is incomplete and the collarette is very nearer to the pupil in pupillary region. During this period the patterns and structures are complete but the pigmentation process is carried out until one year after the birth (Berggren, 1985). The size of the eyeball of a newborn baby is about 18 mm starting from front to back. The eye grows until the age of two and increases in length to 24-25 mm for an adult approximately. The diameter of the iris is 11-12 mm, the radius is 5.5 mm approximately, circumference is about 38 mm and thickness is 0.6 mm at the pupillary margin which is collarette and at the ciliary margin the thickness is 0.5 mm. The pupil which is a hole in the center (so called) occupies one-third of the iris say about nearly 5 mm in diameter and 2.5 mm radius. The edge of the pupil is the collarette which is 1.5 mm away from the pupil as shown in Fig. 2.

The iris is a multilayered structure consisting of anterior layer and posterior layer (Simon *et al*., 1979). The anterior layer is visible and the posterior layer is invisible. The anterior

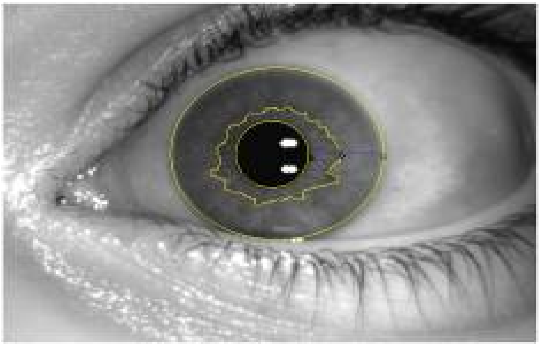

Fig. 2: Pupil, collarette and iris boundary

layer is larger and lies between the cornea and the iris. The posterior layer is smaller and lies between the iris and the lens. The anterior layer consists of the pupillary zone and the ciliary zone. The pupillary zone and the ciliary zone is separated by the collarette which is a circular ridge. The pupillary zone is relatively flat in the iris and the width varies with the degree of atrophy of the anterior border layer. The ciliary zone contains radial interlacing ridges giving an appearance of gossamer. The iris crypts are formed due to the irregular atrophy in the ciliary zone. The anterior border layer of the iris is a loose collagen tissue in which cells are densely packed. The posterior layer is a heavily pigmented epithelial cell.

Proposed geometric features: The geometric features of the iris can also be used for human identification. The structure of the iris is more related to the geometric shape and hence the extraction of these features is also possible. The idea of including iris as biometric feature for human recognition is long back hundred years ago (Bowyer *et al*., 2008), but the computerization of iris recognition system is very young than other biometric system. Dr. Frank Burch an ophthalmologist in the year 1936 recommended iris for the human identification. After a long time in 1985 Dr. Leonard Flom and Aran Safir identified that the two irises of the same person are unique and not same. Then after in 1993 Dr. John Daugman proceeded with the novel approach of Dr. Flom and Safir and effectively automated the iris recognition system in 1994. The Daugman's approach (Daugman, 2004) is based on the frequency domain and he used Integro-differential operator to detect pupil and 2-D Gabor filter phase modulation to extract iriscode. The iriscode was matched using hamming distance. Wildes (1997) approach used Hough transform and gradient edge detection method for pupil detection and Laplacian pyramid for iris image analysis. Boles and Boashash (1998) uses zero-crossing method with dissimilarity functions of matching. The reader can have a thorough review of iris recognition in Burge and Bowyer (2013) study. A precise pupil center and radius is extracted in the study of Xu and Shi (2006). To extract the pupil feature Hough transform is used and a weight ring mask is estimated. In the study of Mohammed *et al*. (2010) the pupil feature is extracted from gray scale image for identification. The Angular Integral Projection Function (AIPF) method is used to accurately detect the center of the pupil and then the boundary points are computed. In the study of He and Shi (2005), feature extraction was based on Daugman approach. The crossed chord segmentation method was used for iris segmentation and zigzag collarette was detected for identification. The geometric based feature in the previous study is used only for medical analysis (Ma *et al*., 2013). In this study, we had attempted to use these geometric features for identification purpose. The geometric features which are extracted can be used as a primary level of identification and some can be used as secondary, for example, the size of the pupil may not be unique but when it is associated with other features say iris or collarette it becomes unique. The geometric characteristics are classified as:

- Pupil based features
- Collarette based features
- Iris based features

Pupil based feature: Pupil is defined to be circular or round but they are not actually a circle. So, the geometrical properties of the circle can be used to identify the pupil and these features can be used for recognition. The following are the pupil based features:

- Pupil Roundness (PR)
- Pupil Largeness (PL)
- Pupil Smoothness (PS)

Pupil Roundness (PR): The roundness measurement requires to trace the iris in 360°C and hence the consistency of the diameter can be measured at a number of orientation points on the iris. In general roundness is defined as a measure of sharpness at the corners and edges of a circle which is related with the sphericity and compactness of the circle. In simple it is the radii around the iris at regular intervals. The roundness feature is calculated based on the diameter at various orientations in Ma *et al*. (2013), where the ratio between the maximum value and the minimum value is calculated at horizontal (h), vertical (v), left (l) and right (r) at 0, 45, 90 and 135°, respectively:

$$\text{Roundness} = \frac{\text{Max}(D_h, D_v, D_l, D_r)}{\text{Min}(D_h, D_v, D_l, D_r)}$$

Given a circle the roundness value is 1.0 for a standard circle, for a non-circular it is less than 1.0 and greater than 1.0 for an irregular shape. Even though the constant diameter is one of the necessary conditions for roundness, it is not sufficient. In this proposed approach we used the assessment procedure Least Square Circle (LSC) which popularly used in the field of metrology to find the roundness of an object. The LSC fits the data at equal spaced angles in the circle which estimates P-R, the non-circularity where R is the radius of the circle and P is the distance from the center of the circle to the point on the path of the circle. The center of the circle is at a point (a, b) in the circle. The radius (r_i) is measured at each angle in 360°. The LSC (y_i) is calculated as:

$$y = \sum_{i=1}^{n} r_i \tag{1}$$

$$Y = r_0 + a\sum_{i=1}^{n}\cos\theta_i + b\sum_{i=1}^{n}\sin\theta_i \tag{2}$$

The minimum difference between the LSC and the measured trace point is defined as:

$$\delta_i = \sum_{i=1}^{n} r_i - \left(r_0 + a\sum_{i=1}^{n}\cos\theta_i + b\sum_{i=1}^{n}\sin\theta_i\right) \tag{3}$$

Hence, the deviation from the LSC is calculated from Eq. 3 and calculate PR as:

$$\Delta z_q = \delta_{imax} - \delta_{imin}$$

where, I = {1, 2, 3, ..., n} and n is the number of measure points on the circle.

Pupil Largeness (PL): The largeness of the pupil is described based on the radius of the pupil. As the pupil is not an actual circle the general diameter calculation of distance from the center to any point on the pupil is not sufficient. The diameter is calculated at eight direction on the pupil at 0° (horizontally), 90° (vertically), 30, 45, 75, 120, 135 and 165°. Hence, the Pupil Largeness (PL) is defined as:

$$PL = \frac{1}{8}\left(0°_{dp} + 30°_{dp} + 45°_{dp} + 75°_{dp} + 90°_{dp} + 120°_{dp} + 135°_{dp} + 165°_{dp}\right)$$

where, dp is the diameter of the pupil.

Pupil Smoothness (PS): The smoothness of the iris can be represented based on the curvature of the circle. The curvature (K) of the circle is defined as the reciprocal of the radius:

$$\left(\frac{1}{r}\right)$$

The curvature of a straight line is 0. As the pupil is considered to be a circle, in this study we have adopted the curvature of circle to measure the pupil smoothness feature (PS):

$$PS = \frac{1}{K}\sum_{k=1}^{k}\rho k - \bar{\rho}$$

where, ρk is curvature and $\bar{\rho}$ is the mean curvature.

The is calculated at the points (X_1, X_2, X_3, ...X_k, ...X_K, X_1) and measured between the angles ($X_{(k+3)}$ mod K-X_k) and ($X_{(k-3)}$ mod K-X_k) the 3rd order curvature is used. The curvature ρk is:

$$\rho_k = \frac{\left(x_{(k+3)} \bmod K - x_k\right)\left(x_{(k-3)} \bmod K - x_k\right)}{\left|\left(x_{(k+3)} \bmod K - x_k\right)\right|\left|\left(x_{(k-3)} \bmod K - x_k\right)\right|}$$

Geometrically the curvature is define as how fast the unit tangent vector to the curve rotates. If the a curve keeps close to the same direction the unit tangent vector change very little and the curvature is small whereas the curve undergoes a light turn the curvature is large.

Collarette based feature: The collarette area is insensitive to pupil dilation and not affected by eyelid or eyelash. The collarette is concentric with the pupil and the radius of the area is restricted certain range. The collarette can be defined as a snaky scalloped line that splits the iris ancillary zone and ciliary zone. The collarette is restricted to the inner half of the iris and contains ether radial spokes or dots. As the collarette based feature cannot be detected directly from the iris it requires some first to detect the collarette and then compute the geometric measures. In the proposed method uses the adjusted angle zigzag sampler to detect the collarette (Strindberg and Buckland, 2004). In the given image the collarette along the line is detected. Here the height of the collarette is denoted as h_s (x) where s is the sampler at the location x along the axis and defined as:

$$h_s(x) = \frac{2w}{\cos\theta(x)}$$

In this case the coverage probability is denoted as π (u) which varies spatially. The vertical component at the point Y, is also used for coverage probability and is π_x (y). For horizontal component it is defined as:

$$\pi_x(x) = \frac{h_s(x)}{H(x)}$$

Hence, by using the horizontal component and vertical component it is easy to estimate the coverage probability. The minimum length of the boundary can be obtained as:

$$L = \frac{\left(x_{max} - x_{min}\right)}{\cos\theta}$$

where, x_{max} is the minimum value of x within the boundary and x_{min} is the maximum value of x within the boundary. In the adjusted angle zigzag line detector the sample height $h_s(x)$ is proportional to the height H(x). Then $\pi_x(x) = \pi_c$ and the mean coverage probability is calculated as:

$$\frac{2w}{\cos\theta(x)\times H(x)} = \frac{2w\times L}{A}$$

Hence, the angle θ(x) is continuously adjusted proportionally to the height H(x). Along the x axis the angle sampler is defined as:

$$(x) = \cos^{-1}\frac{A}{LH(x)}$$

Where:

$$\forall_x \in R_s \subset R, \frac{A}{LH(x)} \le 1, \forall x$$

where, R_s denotes the sample region R.

The algorithm to find ROI_2 the zigzag collarette is as follows:

- Select a point randomly at the collarette region and obtain the θ(x), where:

$$\theta(x) = \cos^{-1}\frac{A}{LH(x)}$$

- Determine the angle of the sample along x-axis using θ(x), find 180°-θ(x)
- Along the x axis extend the sampler from the selected point in both direction by continuously adjusting the angle with respect to θ(x)
- When the upper or lower boundary of R is intersected and the length at x coordinate is obtained
- Continue the above steps until the complete collarette zone is covered

Collarette Roundness (CR): As the collarette feature is extracted from the iris, the next step is working out of geometric feature of the collarette. The roundness feature of collarette is computed as the ratio between the maximum and minimum values of the six diameter of the collarette.

$$CR = \frac{\max(0°_{dc}, 30°_{dc}, 45°_{dc}, 75°_{dc}, 90°_{dc}, 120°_{dc}, 135°_{dc}, 165°_{dc})}{\min(0°_{dc}, 30°_{dc}, 45°_{dc}, 75°_{dc}, 90°_{dc}, 120°_{dc}, 135°_{dc}, 165°_{dc})}$$

where, dc is the diameter of the collarette at various direction.

Collarette Iris Ratio (CIR): The collarette iris ratio is computed based on the diameter of the iris. The diameter of iris is nearly 10-11 mm. The collarette occupies one third of the iris and is located at about 1.5 mm away from the pupil. Hence the distance of the collarette and iris diameter is calculated at eight points, where the iris is divided into equal space ordinates with respect to the polar co-ordinates. For each intersection point on the edge of the iris, the distance is computed and the collarette iris ratio is computed as:

$$CIR = \frac{1}{8}\left(\frac{0°_{dc}}{0°_{di}} + \frac{30°_{dc}}{30°_{di}} + \frac{40°_{dc}}{40°_{di}} + \frac{75°_{dc}}{75°_{di}} + \frac{90°_{dc}}{90°_{di}} + \frac{120°_{dc}}{120°_{di}} + \frac{135°_{dc}}{135°_{di}} + \frac{165°_{dc}}{165°_{di}}\right)$$

where, dc is the diameter of the collarette and di is the diameter of the iris.

Collarette Pupil Ratio (CPR): The collarette pupil ratio is calculated with respect to the collarette and pupil. The same formula used for the CIR can be used to compute CPR but based on the pupil.

$$CPR = \frac{1}{8}\left(\frac{0°_{dc}}{0°_{dp}} + \frac{30°_{dc}}{30°_{dp}} + \frac{40°_{dc}}{40°_{dp}} + \frac{75°_{dc}}{75°_{dp}} + \frac{90°_{dc}}{90°_{dp}} + \frac{120°_{dc}}{120°_{dp}} + \frac{135°_{dc}}{135°_{dp}} + \frac{165°_{dc}}{165°_{dp}}\right)$$

where, dc is the diameter of the collarette and dp is the diameter of the pupil.

Iris based feature: In the proposed work the geometric feature of iris is used for recognition rather than the texture features of iris. The following are the iris geometric features used for recognition:

- Iris Roundness (IR)
- Iris Diameter (ID)

Iris Roundness (IR): The roundness feature of the iris is calculated same as the pupil using the Least Square Circle. The deviation from the LSC is calculated from Eq. 3 and the IR is calculated as:

$$\Delta z_q = \delta_{i\max} - \delta_{i\min}$$

where, i = {1, 2, 3, ..., n} and n is the number of measure points on the circle.

Iris Diameter (ID): This feature is calculated based on the average of diameter at eight point on the iris. It is known that the iris is not an actual circle the general diameter calculation of distance from the center to any point on the outer circle of the iris is not sufficient. Hence, the average diameter of the iris is calculated at eight direction on the pupil at 0° (horizontally), 90° (vertically), 30, 45, 75, 120, 135 and 165°. Hence, the Iris Diameter (ID) is defined as:

$$ID = \frac{0°_{dp} + 30°_{dp} + 45°_{dp} + 75°_{dp} + 90°_{dp} + 120°_{dp} + 135°_{dp} + 165°_{dp}}{8}$$

where, dp is the diameter of the pupil.

Feature fusion and matching: After the iris geometric feature extraction, the iris is represented as a feature vector. The extracted three features are fused into single feature vector as:

Feature vector = {PR, PL, PS, CR, CIR, CPR, IR, ID}

where, PR is Pupil roundness, PL is pupil Largeness and PS is Pupil Smoothness CR is Collarette roundness, CIR is Collarette Iris Ratio and CPR is Collarette Pupil Ratio IR is Iris Roundness and ID is the Average Iris Diameter.

This system is operated at two modes, say identification and verification. During the identification the iris features are extracted and stored in the database. Later at the verification stage the iris features are extracted and matched with the database. As the iris is saved as feature vector, the Euclidean distance measure is used for matching.

RESULTS AND DISCUSSION

The proposed approach is tested on CASIA and Real Time Database. The first database is publicly available dataset CASIA-Iris V3 which consists of 22,035 images from more than 700 subjects. The other is our own real time dataset collected from 800 subjects which consist of 1,600 images. The iris for the real time database was collected environment, where the lighting was maintained and clear instructions were given to the subject in all respect. The performance of the iris recognition system is evaluated using False Acceptance Rate (FAR) and False Reject Rate (FRR).

False accept rate: The frequency of access with wrongful claims of identity or non-identity that are falsely accepted by the system. The FAR is defined as:

$$\frac{FA}{n}$$

where, FA is the number of false access.

False reject rate: The frequency of access with truthful claims of identity or non-identity that are falsely rejected by the system. The FRR is defined as:

$$\frac{FR}{n}$$

where, FA is the number of false access, FR is the number of false reject and n is the total number of access. The system performance can be represented by Receiver Operating Curve (ROC) curve. The ROC curve visualizes the relationship between FAR which is on the x-axis and FRR, the y-axis for the various threshold value. The system was experimented as monomodal and multimodal. From Table 2 it is apparent that the system gives better recognition rate when the features are fused rather than as a mono model. In Table 3 the proposed geometric fused feature is compared with the existing texture based iris recognition and the results proved to have a better accuracy rate.

The proposed method is compared with that of Wildes (1997) and Chen and Yuan (2003). Table 4 shows the accuracy rate against the proposed work and shows a better recognition rate than the existing methods.

As the system is implemented as a monomodal the results are compared as single feature with that of the fused feature as shown from Fig. 3-8 shows the performance of the system with a comparison of collarette and pupillary features. The features are extracted for the CASIA database and the real time database.

Table 2: Comparison of single feature and proposed fused features

Geometric features	FRR (%)	FAR (%)	Accuracy
Pupil based	5.33	4.67	95.23
Collarette based	2.82	3.73	96.51
Iris based	5.36	4.85	93.74
Fused geometric features	2.75	1.23	98.32

Table 3: Comparison of texture feature and proposed features

Iris features	FAR (%)	FRR (%)	Accuracy
Texture based	3.67	4.82	96.45
Fused geometric based	2.75	1.23	98.32

Table 4: Comparison of existing methods with proposed method

Methods	Accuracy
Wildes (1997)	86.49
Chen and Yuan (2003)	91.80
Proposed method	98.32

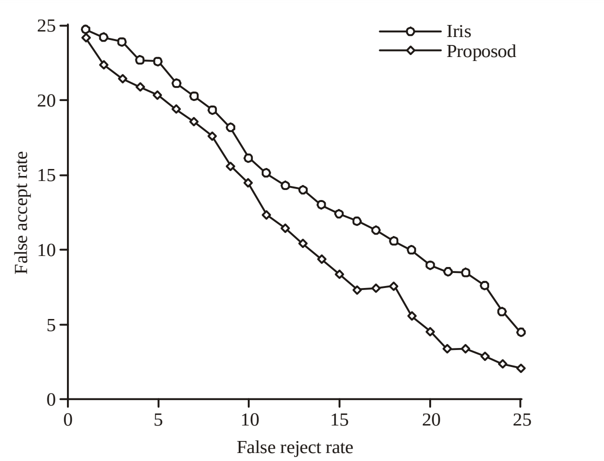

Fig. 3: ROC curve for iris geometric features and proposed fused features

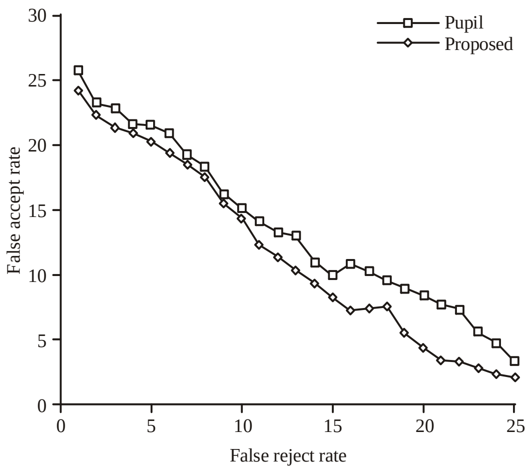

Fig. 4: ROC curve for pupil geometric features and proposed fused features

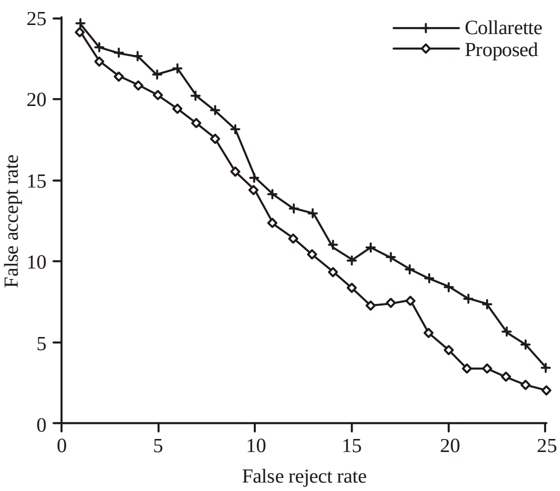

Fig. 5: ROC curve for collarette feature and proposed fused features

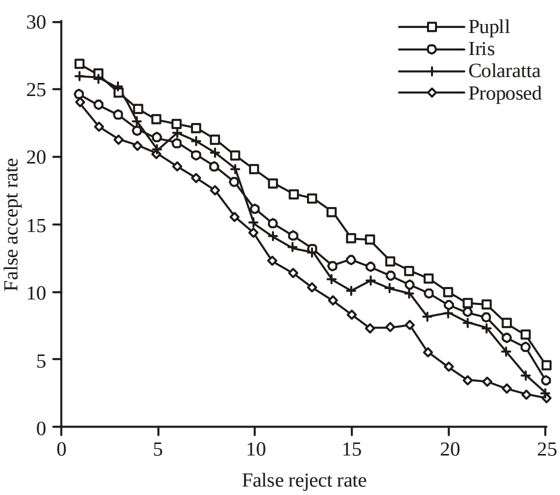

Fig. 6: ROC curve for all geometric features and proposed fused features

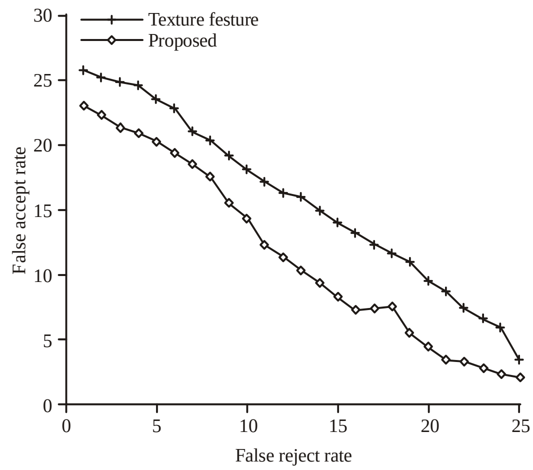

Fig. 7: ROC curve for texture feature and proposed fused features for CASIA DB

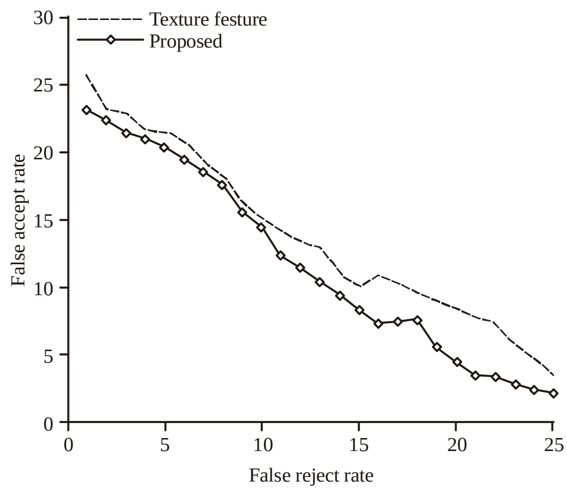

Fig. 8: ROC curve texture features and proposed fused features for Real time database

CONCLUSION

The study presented in this study investigates the feasibility of using geometric features of iris in biometric identification system. The iris features were used for medical analysis and therefore this study is an initiation made using geometric features for human identification. Three different features were extracted and matched. The first feature is based on the pupil's roundness, largeness and smoothness features; the second set of features are based on collarette's roundness, collarette iris ratio and collarette pupil ratio and the third feature is based on iris roundness and diameter. These features of iris was extracted and used for identification as these features are not affected by occlusion such as eyelash or eye lid. The proposed approach was first experimental and the results were analyzed as a single feature. Later the three features were fused as single feature and were matched. The experimental result with this fusion technique proved a better identification than as a single feature and time taken to match is also less.

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