Automatic Multimodal Biometric Identification Using Abnormal Localization Iris and Fingerprint Fusion for High Security

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ABSTRACT :The individual human's unique features and characteristics are used to provide the automatic identification in biometric system. The iris segmentation of biometric identification becomes critical during the cases like abnormal iris. The abnormal iris has to be divided into four quadrature based on the iris left and right centroid points. Then the most dominant quadrature has to be given to feature extraction. The abnormal iris can be classified into four types namely hypo, hyper, exotropia and esotropia. The abnormal iris and face recognition individually were processed using the techniques almost similar in the most of the existing systems. In the proposed system, to improve the performance of individual's recognition the fusion technique is applied between abnormal iris and face images of the same human. The quality of the biometric images affects the performance of the recognition system. The low quality of biometric images has been one of the important problems in human biometric recognition from a distance using its traits in face and abnormal iris. The restoration and enhancement techniques are used to remove the noises and improve the contrast and brightness of the image in order to improve the resolution in the pixel domain. The iris segmentation technique is applied to estimate the inner and outer ring of the abnormal iris image and separate the annular iris portion from the eye image by eliminating the eye lids and lashes. The Gabor filters and Hamming distance techniques are used for feature extraction and feature matching from the segmented iris image in the Cartesian coordinate system in zero-crossing representation of the wavelet transform is proposed to two special on region of annular. The short time Fourier Transform (STFT) is applied for fingerprint to reconstruct the ridges and furrows from the non-station 2D signals. All the intrinsic properties of the image like region masking, orientation of ridge and ridge frequency are all estimated using STFT analysis. The image fusion technique is used to combine the relevant first order features from a fused image. The pixel level image fusion based on Principle Component Analysis (PCA) technique is used to fuse the both the iris and fingerprint images after image registration process. The fused image features are more useful to give higher range of accuracy in recognition. The matching technique is applied to evaluate two pair of feature points and estimate similarity between testing image sets. The probabilistic neural network (PNN) is used for matching and recognizing the multimodal biometric for security purpose.

Keywords: Biometric, Gabor Filter, Hamming Distance, STFT, Intrinsic properties, PNN, PCA.

INTRODUCTION

The biometric recognition system is the one of the major applications of human unique feature based identification that is mainly used in recent days that can be applied in Identity validation, identity authentication and recognition. The Iris and fingerprint patterns are unique in human beings, and always cannot be changed. The pattern may be damaged due to aging effect or any attacks during accidents. Those affected region of biometric pattern can be reconstructed by applying image restoration and enhancement algorithm during recognition.[1]

The iris image processing system is classified into 4 stages. In the first stage, the preprocessing level 1 is applied for de-noising the image by applying the proper 2D filtering technique. [2] In the second stage, the preprocessing level 2 is applied for enhancing the contrast and brightness of the image. Thus, the quality of image is improved in terms of PSNR in higher rate. In the third stage, for the iris segmentation process, the Canny edge detection is applied to detect the boundaries of the iris image.[3] Then Circular Hough transform is applied to estimate the iris circle diameter. In the fourth stage, the feature extraction is done based on the wavelet decomposition method and then iris image is fused with fingerprint image for recognition purpose using PNN.[4]

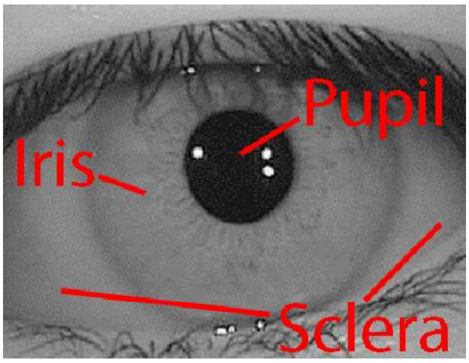

Figure 1: An eye image model

Usually, the fingerprint images are low quality images during capture the impression of the image. The Short Time Fourier Transform (STFT) analysis is used to enhance the fingerprint image. The STFT is the improved algorithm in 2D image processing to process the non stationary signal. The proposed algorithm calculates all the intrinsic properties of the given image like region masking, orientation of the image and frequency of the image. Once the fingerprint image is qualified in terms of improved ridges and furrows using STFT analysis, the improved fingerprint image is fused with iris image using PCA algorithm to estimate more features for recognition using PNN.[5]

The fingerprint feature extraction technique is highly dependent on the input fingerprint image only. The fingerprint image quality cannot be particularly estimated, it is fairly depends on the contrast and brightness of the ridge orientation structure of the input image only. The high quality image has high contrast and brightness and good ridges and furrows structure. The robustness of the authentication can be improved by applying the enhancement technique on the fingerprint image that leads to the proper feature extraction from the image.[6]

PROPOSED ALGORITHMS

1. Image restoration using Adaptive anisotropic diffusion filter
2. Image enhancement using contrast limited adaptive histogram equalization
3. Image segmentation using canny edge detection and Circular Hough Transform
4. Image Feature extraction using wavelet decomposition.
5. Fingerprint enhancement using STFT
6. Iris and Fingerprint Image fusion using PCA
7. Image recognition using PNN

BLOCK DIAGRAM

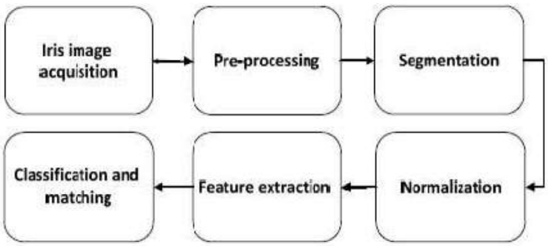

Figure 2: Block diagram

The above figure shows that the iris segmentation process.

Figure 2: Block diagram for proposed iris and fingerprint fusion technique for higher security

LITERATURE SURVEY

Gabor filters: An image enhancement technique has both selective and orientation-selective properties. Based on the parameters like local orientation and ridge frequency around each pixel Gabor filters is applied for each pixel on the image. This method estimates the ridge orientation using contiguous range of directions. This filter increases the contrast between fore ground and background ridges reducing the noise effectively. But it is computationally expensive.[7]

Directional Fourier: The image enhancement process begins by firstly computing the orientation image. Uses set of direction to calculate the direction. [8]

Minutiae based partial finger print recognition system: Uses localized secondary features and flow network based brute-force matching. This method overcomes the drawbacks of the conventional approaches.[9]

Fast Fourier transform and Gabor filters: used to enhance and reconstruct the information of the finger print image. Extracted features are used to perform recognition.

Phase-based and feature-based finger print matching: A good recognition performance is achieved compared with minutiae-based finger print algorithm.

Image preprocessing

The input image is affect by impulse noise, the typical poverty model at point (i, j) in a 2D matrix can be written as

$$y(i, j) = x(i, j) + n(i, j), \quad (1)$$

Where x, y, and n represent an input image, the noisy image, and the impulse noise, respectively. For successful filtering, it is popular to get a reliable degradation estimation function that can find the degree of the noise as well as the noise's pixels [10]. The adaptive median filter reflects on all pixels in the image in roll and seems at its close by adjacent pixels to choose whether or not it is representative of its background [11]. Instead of restore the pixel value with the mean of neighbor's pixel values, it is restored with the median of those values. A pixel that is different from a majority of its surroundings and being not properly managed with those mentioned pixels, to which it is comparable, is tagged as a noise. These noise pixels are restored by the median rate of the pixels in the surrounding that have moved the noise test. Thus, the AMF resolve the double purpose of extracting the noise from the image and dropping deformation in the image.[12]

Step 1: Image Acquisition

Step2: Apply Adaptive Median Filter for both Gray and Colour space Images

Step3: Subtract the Filtered Image from Input Image

Step4: Calculate the Noisy Pixels.

Let X (.,.) and Y (.,.) be the input and output respectively, of the adaptive median filter. The

Y (i, j) =median{X (i-s, j-t)|(s, t) W} --------- (3.1)

Here W is the window that is defined in terms of image co-ordinate the neighborhood of the origin.

As shown in figure 3,the image restoration is the process of removing the noise content present in the image initially. The restoration is performed by reversing the process that blurred the image. The image is restored using adaptive anisotropic diffusion filter [13]. Adaptive Anisotropic diffusion filter is also known as perona malik diffusion filter. It aims at reducing the image noise without removing significant parts of the image content. It removes the noise from the digital images without blurring edges. The simplest and best method used for smoothing images is to apply a linear diffusion process. It uses convolution between image matrix and square kernel matrix. The size of the kernel is calculated using the given formula

a(x,y)= 1/(2πσ*σ)exp{-(x*x+y*Y)/2σ*σ}

Adaptive Anisotropic diffusion equation $\mathbf{I}_t =$ $\operatorname{div}(c(x,y,t)\nabla I) = \mathbf{c}(\mathbf{x},y.r)\Delta I + \nabla c\, \nabla I$

Where, it is indicate with div the divergence operator, and with ∇ and Δrespectively the gradient and Laplacian operators, with respect to the space variables. It reduces to the isotropic heat diffusion equation $\mathbf{I}_t$= **c ΔI**if c(x , y, t) is a constant. Suppose that at the time (scale) t, it is known the locations of the region boundaries appropriate for that scale. It would want to encourage smoothing within a region in preference to smoothing across the boundaries. This could be achieved by setting the conduction coefficient to be 1 in the interior of each region and 0 at the boundaries Figure 1 shows that the image given as the input for the preprocessing. The Adaptive anisotropic diffusion filter is applied to noise the noisy input image.

The noises are completely eliminated in the restoration process.

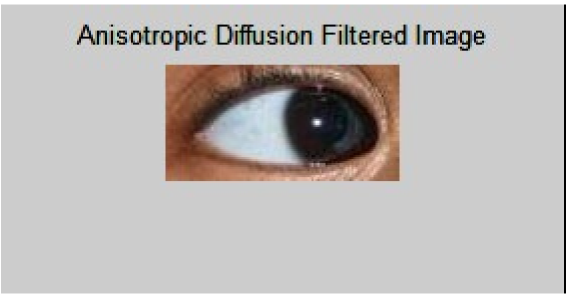

Figure 3: Image preprocessing using Adaptive Anisotropic Diffusion Filter

Image enhancement is the process of adjusting digital image so that the results are most suitable for display. It is used to improve the quality of the image. The **Adaptive Mean Adjustment**[14] is used to enhance the image.Adaptive Mean Adjustment is a computer image processing technique used to improve contrast in images. It modifies the allocation of the pixels to become more consistently increase out more than the obtainable pixel variety. In histogram dealing out, a histogram displays the sharing of the pixel intensity values. Dark image will have low pixel values whereas a bright image will have high pixel values.

CLAHE [3] formula is given by,

CLAHE = X(I,j)-Xmin(I,j)/Xmax(I,j)- Xmin(I,j) (1)

Where ,X is the image,Xmin-Minima of the image,Xmax-maxima of the image.

The main aim of the image enhancement is to improve the contrast and brightness of the image in order to improve the quality of the image .

The image is considered as a function z=f(x,y), it is an 2D matrix.

Where z is the gray level of the image.

f(x,y) = a1*x +a2*y + a3 +e(x,y), --(2)

Calculate the values a1, a2, a3, i.e. $\hat{a}1$, $\hat{a}2$, $\hat{a}3$,

We have to reduce the sum of square of residuals at each pixel,

$$S^2 = \sum_x \sum_y [\hat{a}1 * x + \hat{a}2 * y + \hat{a}3 - f(x,y)]^2, \quad (3)$$

It gives

$\hat{a}1$, $\hat{a}2$, $\hat{a}3$ by

$$\hat{a}1 = \frac{\sum_x \sum_y x * f(x,y)}{\sum_x \sum_y x^2},$$

$$\hat{a}2 = \frac{\sum_x \sum_y y * f(x,y)}{\sum_x \sum_y y^2},$$

$$\hat{a}3 = \frac{\sum_x \sum_y f(x,y)}{\sum_x \sum_y 1}. \quad (4)$$

$$F = \frac{[(\hat{a}1 - a1)^2 \sum_x \sum_y x^2 + (\hat{a}2 - a2)^2 \sum_x \sum_y y^2]/2}{S^2/(n-3)} \quad (5)$$

Thus,

F has an F distribution with 2,n-3 degree of freedom.

When considering 3*3 window, n-3= 6.

Now we derive the following. Change f(x,y) by equation (2) ,

ie.,

a1*x +a2*y + a3 + e(x,y) ,

$$\hat{a}1 = a1 + \frac{\sum_x \sum_y x * e(x,y)}{\sum_x \sum_y x^2},$$

$$\hat{a}2 = a2 + \frac{\sum_x \sum_y y * e(x,y)}{\sum_x \sum_y y^2},$$

$$\hat{a}3 = a3 + \frac{\sum_x \sum_y e(x,y)}{\sum_x \sum_y 1}. \quad (6)$$

From above equation and noise equation, it drives variances of $\hat{a}$ 1, $\hat{a}$ 2, $\hat{a}$ 3

$$\sigma_{\hat{a}1}^2 = \frac{\sigma^2}{\sum_x \sum_y x^2,} \qquad \sigma_{\hat{a}2}^2 = \frac{\sigma^2}{\sum_x \sum_y x^2,}$$

$$\sigma_{\hat{a}3}^2 = \frac{\sigma^2}{\sum_x \sum_y x^2,} \quad (7)$$

the covariance is 0, nN

Now noises are un-correlated for pixels.

From equations (2) (4) (6):

$$S^2 = \sum_x \sum_y e^2(x,y) - (\hat{a}1 - a1)^2 \sum_x \sum_y x^2 - (\hat{a}2 - a2)^2 \sum_x \sum_y y^2 - (\hat{a}3 - a3)^2 \sum_x \sum_y 1. \quad (8)$$

Now e(x,y) ~ N(0),

$$\frac{\sum_x \sum_y e^2(x,y)}{\sigma^2} \sim \chi_n^2, \quad (9)$$

The χ_n^2 → for the chi-squared distribution with n degrees of freedom, n can be calculated as,

$$n = \sum_x \sum_y 1. \quad (10)$$

Because e(x,y) is a normal distribution function, based on the equation (6), $\hat{a}$ 1, $\hat{a}$ 2, $\hat{a}$ 3 gives the normal distribution :

$\hat{a}$ 1~ N(a1, $\sigma_{\hat{a}1}^2$), $\hat{a}$ 2~ N(a2, $\sigma_{\hat{a}2}^2$), $\hat{a}$ 3~ N(a3, $\sigma_{\hat{a}3}^2$), (11)

with the variance given in equation (23), so

$$\frac{(\hat{a}1 - a1)^2}{\sigma_{\hat{a}1}^2} = \frac{(\hat{a}1 - a1)^2 \sum_x \sum_y x^2}{\sigma^2} \sim \chi_1^2,$$

$$\frac{(\hat{a}2 - a2)^2}{\sigma_{\hat{a}2}^2} = \frac{(\hat{a}2 - a2)^2 \sum_x \sum_y y^2}{\sigma^2} \sim \chi_1^2,$$

$$\frac{(\hat{a}3 - a3)^2}{\sigma_{\hat{a}1}^2} = \frac{(\hat{a}3 - a3)^2 \sum_x \sum_y 1}{\sigma^2} \sim \chi_1^2. \quad (12)$$

Following the equations (9), (10), (12) ,

$$\frac{S^2}{\sigma^2} \sim \chi_{(n-3)}^2, \quad (13)$$

U~ χ_j^2 , V ~ χ_k^2 , then

$$\frac{U/j}{V/k} \sim F_{j,k.}$$

$$\frac{[(\hat{a}1 - a1)^2 \sum_x \sum_y x^2 + (\hat{a}2 - a2)^2 \sum_x \sum_y y^2]/2}{S^2/(n-3)} \sim F_{2,n-3.} \quad (14)$$

DN (Digital number)

Estimate the Digital Number (DN) as

DN = WF * RV + (1-WF) * DN (old), (15)

RV - > Reference value for the pixels

WF - > Weight vector

WF = max (WF1, WF2) (16)

The contrast of the image is calculated as follows,

(Image contrast enhancement)

$$WCON = \frac{DN\max(window) - DN\min(window)}{DN\max(image) - DN\min(image)} \quad (17)$$

Iris segmentation

The concept of fragility of a few bits in the iris codes regards exclusively their inside-magnificence variant, i.e., the probability that they take one of a kind values in templates computed from abnormal iris of the equal iris. Regarding the primary circle of relatives, strides have been given to enhance the recognition performance in opposition to difficult subjects, acquisition artifacts, and inter-sensor operability. We have proposed an adaptive personalized matching scheme that highlights the discriminating functions of each iris points and augments the robustness. We used the sparse representation for class algorithm in randomly projected iris patches, which became located to improve the robustness against segmentation mistakes and acquisition artifacts. The opportunity to perform reputation in information received from more than one styles of sensors encouraged the algorithm proposed, that learns transformations between records acquired via unique sensors and keep away from that customers are re-enrolled whenever a new sensor is deployed.

An elliptical parameterization changed into chosen for both iris limitations, the use of the random elliptic Hough transform. Based at the parameterization of the pupillary and scleric iris boundaries, the interpretation into the dimensionless pseudo-polar coordinate device changed into finished in keeping with the Daugman's rubber sheet model. The quantity of statistics available in small iris patches was measured via the Shannon entropy criterion, quantifying (in terms of bits) the anticipated cost for the amount of information in rectangular areas p×p of the normalized image I:

$$h(I_{p\times p}) = -\sum_{i} P(I_{p\times p} = i)\log_2\left(P(I_{p\times p} = i)\right)$$

where $P(I_{p\times p} = i)$ is the probability for the *ith* intensity in the patch.

The artifacts should be properly removed by applying the image preprocessing technique as shown in figure 2 to estimate the proper feature extraction. The important process in the iris recognition is to be iris segmentation . The iris portion can be estimated by two circles, those are pupil /iris boundary and another one is iris/sclera boundary. The input image taken is iris an annular pattern between the sclera and pupil in this the sclera is an outer boundary and pupil is inner boundary. Many iris segmentation patterns are available in the field of image processing. In the proposed system the Circular Hough Transform with edge detection for contour findings is applied to segment the iris from the eye image. The edges of iris image can be estimated by using edge detection .The Circular Hough transform is used to estimate the centers and radius of the two above boundaries. The geometric shapes can be detected by applying Hough transform that is written as parametric equations such as circles and lines. The known radius of circular image can be estimated by applying Circular Hough Transform (CHT) . The circle equation can be written as,

r^2=(x-a)^2+(y-b)^2 - -(18)

Where r denotes radius and a and b are the center coordinates of an image. The points on the equation of circle in parametric equation can be written as,

x=a+rcos(θ) –(19)

y=b+rsin(θ) – (20)

The edge image is calculated to compute the transform from the every point of radius. The coordinates was increased by 1 unit at every point of the perimeter of a circle passes on the image [8].

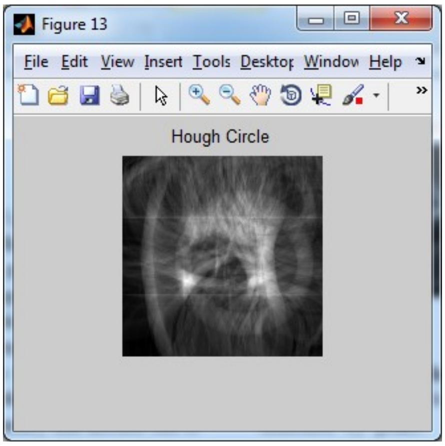

Figure 4 a: Circular Hough Transform Image

In this way the array is created to store the circle indicated by peaks. The array is called as Hough space of circular image. Using this transformation, the circles are detected based on the knowledge of radius. For each radius examined, the maxima are estimated to find out the location and value . The figure 4 shows that the output of CHT. The image is decomposed of many circles with given location and value of CHT. Finally the pupil and iris are located based on the coordinates.

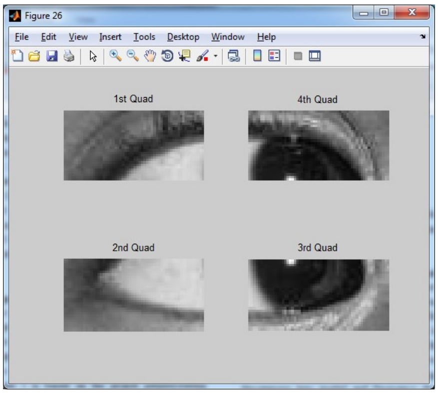

Figure 4b. Abnormal Iris 4 quadrature separation

The figure 5 shows, only the iris is localized edge image using CHT. If the CHT could not able to find out edges of iris and pupil boundary properly then the localization is not possible. The exact localization is formed as shown in figure 5 is based on the proper preprocessing and edge detection using canny method.

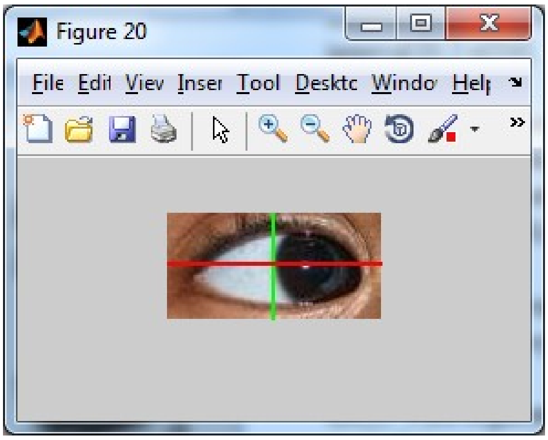

Figure 5: Iris segmentation

Polar mapping

The Daugman's Rubber Sheet Model is used to process the iris image normalization transformation of the segmented iris image to have correct dimensions to have proper evaluation.

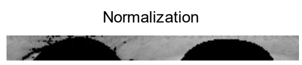

Figure 6: Normalized image using Daugman's Rubber Sheet Model

The Daugman's Rubber Sheet Model joins every point in the segmented iris portion to a couple of coordinates (r,θ). Where r is lie in between the interval [0,1] and θ is the angle in between the interval [0,2 π] [4].

The Cartesian coordinates to the normalized non-concentric polar coordinates of iris model from (x,y) coordinates formed by,

I(x(r,θ),y(r, ,θ) →I(r,θ) (21)

Using,

x(r,θ)=(1-r)xp(θ)+rxi(θ) (22)

y(r,θ)=(1-r)yp(θ)+ryi(θ) (23)

Where,

I(x,y) →iris segmented image,

(x,y) →Cartesian Coordinates,

(r,θ) → Polar coordinates with normalization

(xp(θ), yp(θ)) and (xi(θ), yi(θ)) → pupil and iris boundaries coordinates

Feature Extraction using Wavelet Transform

The 2D wavelet transform presents an exact root for images because of its useful features extracted from the image. The capability to dense the majority of the data's energy into a only some transformation coefficients, that is called energy compaction. The discrete wavelet transform is applied to the iris image to decompose into spatial and frequency domain. The 4 sub-band are applied the decomposition to half the dimension of the iris image. The decomposition will be LL,HL,LH and HH with respect to low-low decomposition that is the lower resolution coefficients, the high-low band that gives vertical coefficients, the low-high band that gives the horizontal coefficients and the high-high band that gives the diagonal coefficients. The Haar wavelet transform can be written as,

$$H = \frac{1}{\sqrt{4}} \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 \\ \sqrt{2} & -\sqrt{2} & 0 & 0 \\ 0 & 0 & \sqrt{2} & -\sqrt{2} \end{bmatrix} \quad (24)$$

Fingerprint enhancement using STFT analysis

The intrinsic images signify the significant properties of the fingerprint image as a pixel mapping that comprise the ridge frequency image, the ridge orientation image and the region mask. . The calculation of the intrinsic images makes a very vital step in the feature extraction and in the process of image matching. The orientation image O indicates the direct orientation at fingerprint image point.

Figure 7: Low Quality input fingerprint image

The low quality input fingerprint image is shown in the figure 7. There are some approaches are possible to estimate the orientation image from fingerprint. The ridge orientation of image varies slowly on the image excluding in the region of singularities like delta and core [9]. In the orientation image, the non overlapping block size is fixed as W x W. Thus Gx (x,y) and Gy (x,y) are the horizontal and vertical gradients respectively. The gradients are estimated using Sobel edge detection [14].

The block orientation θ is estimated using, $\theta = \frac{1}{2}\tan^{-1}\frac{G_{yy}}{G_{xx}}$ where,

$$G_{xy} = \sum_{u \in W} \sum_{v \in W} 2G_x(u,v)G_y(u,v) \quad (25)$$

$$G_{xx} = \sum_{u \in W} \sum_{v \in W} G_x^2(u,v) - G_y^2(u,v) \quad (26)$$

The dominant orientation so attain still holds variations basis by creases and ridge breaks. The orientation image is smoothened by vector averaging by utilizing the regularity property of the fingerprint image.

The ridge frequency is a one important intrinsic property of the fingerprint image. As like above property, the ridge frequency is also slowly varying property to estimate the again for each non-overlapping block of the image with size WxW. The average inter-ridge image distance within a block of the image that is computed using the projection sum described along a line projected orthogonal to the ridges or based on the difference of gray indication in a window orientation orthogonal to the ridge flow of the image. This method is created based on the reliable extraction of the local ridge orientation. A sinusoidal signal and the distance between any two peaks gives the inter ridge distance provides the projection sum.

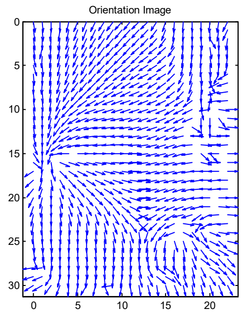

Figure 8: Ridge Orientation of fingerprint image

The region mask is used to describe the sections of the image there ridge structures are available in the coordinates. It is also called as foreground mask and it is used to remove spurious features which may happen outside of the fingerprint region. The process of enhancement is a complicated problem in the region of more curvature close to the core and deltas those have high dominant direction. Exceptionally low angular bandwidth provides spurious artifacts and ridge discontinuity in the image. The ridge orientation image is estimated from the input fingerprint image as shown in the figure 8. In the case of poor quality images, most of the algorithms are not reliable in singular point location. Thus we estimate the coherence image for improving the quality of the image that is useful in feature extraction and recognition of the fingerprint images.

The dispersion measure of circular data of coherence is written as,

$$C(x_0, y_0) = \frac{\sum_{(i,j)\in W} |cos(\theta(x_0, y_0) - \theta(x_i, y_i))|}{W \times W} \quad (27)$$

If the orientation of central block θ(x0,y0) is same to each pixel of neighbor θ(xi,yi) then the coherence will be high.

In the enhancement process using STFT, there are two stages are used. In the first stage, there is important process to compute the intrinsic image of fingerprint. The image is classified into windows with overlapping. We consider that the image is a stationary within the small window and that can be shows as approximately as surface wave.

In the small region, the Fourier spectrum is established and probabilistic computes of the ridge orientation and ridge frequency are obtained as outlined. We have to apply filter in each window that is tuned to the radial frequency and that is formed with the dominant ridge direction.

$$H(\rho, \phi) = H_\rho(\rho) H_\phi(\phi) \quad (28)$$

$$H_\rho(\rho) = \sqrt{\left[\frac{(\rho\rho_{BW})^{2n}}{(\rho\rho_{BW})^{2n} + (\rho^2 - \rho_0^2)^{2n}}\right]} \quad (29)$$

$$H_\phi(\phi) = \begin{cases} \cos^2 \frac{\pi}{2} \frac{(\phi - \phi_c)}{\phi_{BW}} \text{if} |\phi| < \phi_{BW} \\ 0 \text{otherwise} \end{cases} \quad (30)$$

Here $H_\rho(\rho)$ is a band-pass butter-worth filter with center defined by ρ_0 and bandwidth ρ_{BW} is derived from the intrinsic orientation image while the bandwidth ρ_{BW} is chosen to be inversely proportional to the angular coherence measure. The angular filter is a raised cosine filter in the angular domain with support ϕ_{BW} and center ϕ_c. The figure 9 shows that the fingerprint reconstructed image using STFT analysis with high quality and improved contrast and brightness.

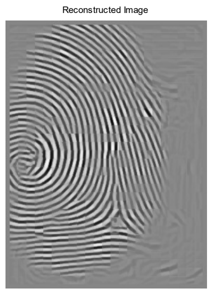

Figure 9: Reconstructed fingerprint image using STFT analysis

The fingerprint metric are calculated to justify the image enhancement using STFT analysis.

MSSIM (Structure Similarity Measuring)

$$SSIM(x, y) = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)}. \quad (31)$$

MSE (Mean Squre Error)

$$\frac{1}{MN}\sum_{j=1}^{M}\sum_{k=1}^{N}(x_{j,k} - x'_{j,k})^2 \quad (32)$$

PSNR (Peak Signal to Noise Ratio)

$$10 \log(255^2 / MSE) \quad (33)$$

NK (Normalized Co-relation)

$$NK = \frac{\sum_{j=1}^{M}\sum_{k=1}^{N} x_{j,k} . x'_{j,k}}{\sum_{j=1}^{M}\sum_{k=1}^{N} x^2_{j,k}} \quad (34)$$

SC (Structured Content)

$$SC = \sum_{j-1}^{M}\sum_{k-1}^{N} x_{j,k}^2 / \sum_{j-1}^{M}\sum_{k-1}^{N} x'^2_{j,k} \quad (35)$$

NAE (Normalized Absolute Error)

$$NAE = \sum_{j=1}^{M}\sum_{k=1}^{N} |x_{j,k} - x'_{j,k}| / \sum_{j=1}^{M}\sum_{k=1}^{N} |x_{j,k}| \quad (36)$$

Table 1: Fingerprint enhancement feature metrics

DB3 Results	Equal Error Rate
Without Enhancement	10.35%
With Enhancement	6.5%
PSNR	59 dB
MSE	0.00032
MSSIM	0.9836
NK	0.999
SC	1
NAEC	1.9378e^-008

Image Fusion

Image fusion is the technique used to extract and understand more information from different types of images. After image fusion, the resultant image has more informative content than the input images that are before fusion. Also, the image fusion is the technique that is used to improve the image characteristics like contrast and brightness of the image. In the proposed system, the fingerprint image and iris images are fused after the image registration process to precede different size of images. The proposed method called principle component analysis (PCA) is the mathematical solution that transforms correlated things into uncorrelated things. It is used to estimate compressed and optimal explanation of the images. The direction with the maximum variance is considers as first principal component. The subspace perpendicular to the first principle component is considered as the second component. After the image fusion, the fused image should preserve all suitable and practical pattern information from the input images. The performance measures are estimated to validate some quantitative analysis after the proper fusion.

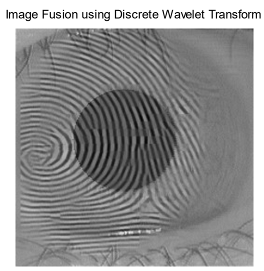

Figure 10: Fused Image using PCA algorithm

1) The re-sampled bands of the multi-spectral image to the same resolution as the panchromatic image are transformed by the principal component transformation.

2) The panchromatic image is histogram matched to the first principal component. This is done in order to compensate for the spectral differences between the two images, which occurred due to different sensors or different acquisition dates and angles.

3) The first principal component of the multi-spectral image is replaced by the histogram matched panchromatic imagery.

4) The new merged multi-spectral imagery is obtained by computing inverse of principal component transformation.

After image fusion, the features are extraction using following equations,

Peak Signal to Noise Ratio (PSNR)

PSNR is the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation [2][9]. The PSNR measure is given by:-

$$PSNR(dB) = 20log\frac{255\sqrt{3MN}}{\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}\left(B'(i,j)-B(i,j)\right)^2}} \quad (37)$$

Where B → any image

B' → fused image to be assessed

i – Pixel column index

ENTROPY

Entropy is an index to evaluate the information quantity contained in an image. If the value of entropy becomes higher after fusing, it indicates that the information increases and the fusion performances are improved. Entropy is defined as:-

$$E = -\sum_{i=0}^{L-1} p_i \, log_2 \, p_i \quad (38)$$

Where L is the total of gray levels, p={p0,p1,…Pl-1} is the probability distribution of each level.

NORMALIZED CROSS CORRELATION (NCC)

Normalized cross correlation are used to find out similarities between fused image and registered image is given by the following equation

$$NCC = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}(A_{ij} * B_{ij})}{\sum_{i=1}^{m}\sum_{j=1}^{n}(A_{ij})^2} \quad (39)$$

Table 2

S. No	Parameters	Values
1	PSNR	53.388
2	MSE	7.4076e-10
3	Entropy	12.2243
4	Auto correlation	45.8421
5	Contrast	5.4594
5	Cluster Prominance	244.4854
6	Dissimilarity	0.00656
7	Sum of Squares	45.7612
8	Sum of Average	12.0160
9	Energy	0.5835
10	NCC	0.6521

Recognition using PNN Classifier

We proposed the PNN classification method to recognize the fused image based on the features is extracted from the fused image. Probabilistic Neural Network (PNN) is a mainly used Classification system that is based on feed-forward Neural network. Also PNN has been used in numerous submissions in bioinformatics. PNN is much faster and more accurate than other neural networks. The probabilistic neural network is a subset of RBN and can computes the functions properly. We used a PNN with 4 layers of given nodes which have Input layer, Pattern layer, Summation layer, Output layer. Figure 11 shows the structure of PNN.

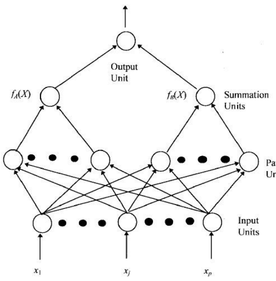

Figure 11: PNN Classifier

Table 2: Image fusion feature tabulation

S. No	Parameters	Values in Percentage
1	Accuracy	98.83
2	Sensitivity	97.38
3	Specificity	97.98

Table 3: Accuracy testing using Confusion Matrix

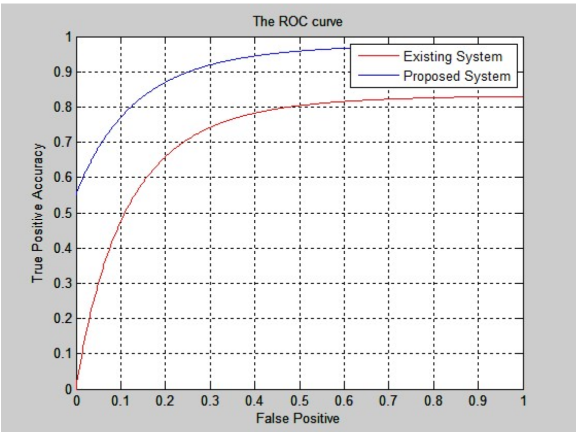

Figure 12: ROC Graph

The figure 12 shows that the roc graph of accuracy testing for the proposed system. A test with perfect discrimination (no overlap in the two distributions) has a ROC curve that passes through the upper left corner (100% sensitivity, 100% specificity). Therefore the closer the ROC curve is to the upper left corner, the higher the overall accuracy of the test. (Zweig & Campbell, 1993).

CONCLUSION

Iris and fingerprint patters have been implemented to be useful and exact in identifying and authenticating the human beings. For iris image processing, we have implemented the iris image segmentation, normalization, feature extraction and recognition phases. The Hough transform plays major role in detecting the iris portion from the eye image. The eyelash and eyelid artifacts are properly eliminated by applying the segmentation process. All the phases are accurate and precision as given the calculated accurate parameters using confusion matrix. The fingerprint image is also used to provide the unique feature of the human being. The low quality and damaged fingerprint image can be reconstructed by applying the STFT analysis. By applying PCA algorithm based image fusion technique, the fingerprint image and iris images are fused to extract more information to increase the accuracy of the recognition process. The PNN classifier is used to recognize the fused image based on the features is extracted from the fused images.

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