Use of Physiological Characteristics for Personal Authentication

Aditya Nigam
Supervisor: Dr. Phalguni Gupta

Department of Computer Science and Engineering
Indian Institute of Technology Kanpur

April 25, 2011

Table of contents

Problem Definition and Motivation

- Biometric based Personal authentication systems are in demand.
- Several biometric traits are studied such as face, iris, palmprint, ear, fingerprint etc.
- Biometrics based PAS:

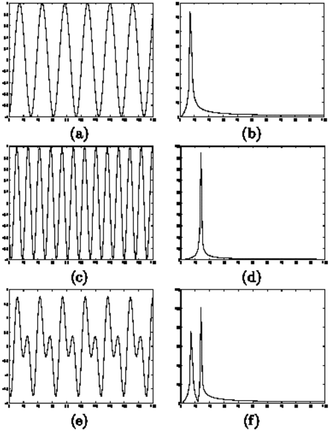
  Authentication Problem: One to One matching and decide using thresholding (Verfication).

  Identification Problem: One to Many matching and best matching scores and corresponding subjects are reported (Recognition problem)

Fourier Analysis

- Spatial frequencies and their orientations are important characteristics of textures in images.
- They can be analyzed using spectral decomposition methods like Fourier analysis.

- In figure (a),(c) their are 2 sinusoids and their corresponding magnitude of Fourier spectrum is shown in figure (b),(d).
- The peak corresponds to the frequency of the sinusoid.
- Key Problem: Spectral features from different signal regions are mixed together. It basically gives the global features.



Gabor Filter

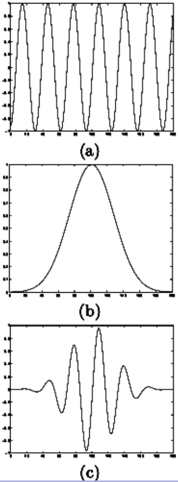
- Many image analysis applications requires spectral features that are extracted in a spatially localized manner. Most popular tool for local feature extraction is Gabor filter.

- Gabor filter is obtained by modulating a sinusoid with a Gaussian envelope.
- 2D - Circular gabor filter is defined as:

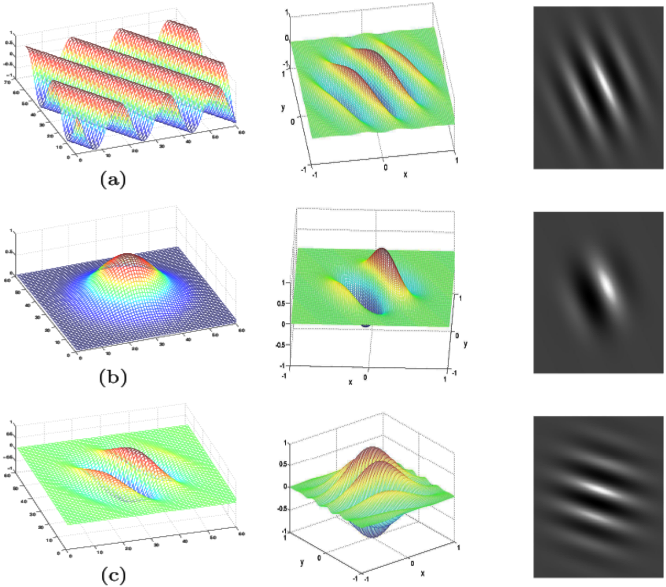
$$G(x, y, \theta, \mu) = \frac{1}{2\pi\sigma^2} * e^{-(\frac{x^2+y^2}{2\sigma^2})} * e^{\{2\pi i(\mu x cos(\theta)+\mu y sin(\theta))\}} \quad (1)$$

where μ is the spatial frequency of sinusoidal wave, σ is the standard deviation of the Gaussian envelop and θ controls the orientation of the function.

- The response of gabor filter to an image is obtained by 2D Convolution operator.

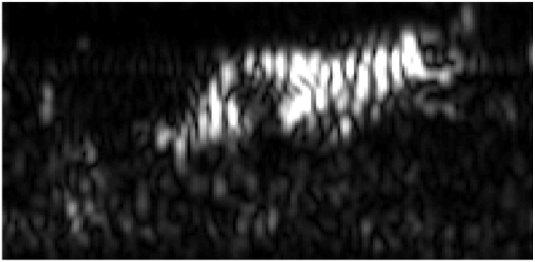


Gabor Filter



Gabor Filter

(a)



(b)

Figure: Gabor Response

PALMPRINT Based PAS

- **Online Palmprint Identification**
  Zhang, David, Kong, Adams Wai-Kin, You, Jane, and Wong, Michael
  IEEE Trans. Pattern Anal. Mach. Intell. 25(9), volume 25, 10411050, 2003.
- **Competitive Coding Scheme for Palmprint Verification**
  Kong, Adams Wai-Kin, and Zhang, David
  ICPR (1), 520523, 2004.
- **Palmprint Identification using Feature-Level Fusion**
  Kong, Adams, Zhang, David, and Kamel, Mohamed
  Pattern Recogn. 39, volume 39, Elsevier Science Inc., 478487, March 2006.
- **Palmprint based Recognition System using Phase-Difference Information**
  Badrinath, G.S, and Gupta, P
  Journal of Future Generation Computer Systems, 2011.
- **Palmprint Recognition Based on Local DCT Feature Extraction**
  Choge, H. Kipsang, Oyama, Tadahiro, Karungaru, Stephen, Tsuge, Satoru, and Fukumi, Minoru
  Proceedings of the 16th International Conference on Neural Information Processing: Part I, Springer-Verlag, 639648, 2009.
- **An Efficient Palmprint based Recognition System using DCT Features**
  Badrinath, G.S, and Gupta, P
  Pattern Recognition Letters, April 2011.

PALMPRINT (Palm Code - 2003)[13]

3 Key Issues in Palmprints

- Acquisition : How to obtain good quality images quickly (1 *second*).
- Representation : How to extract features suitable for identification. How to represent efficiently.
- Identification : How to search for a query fast within a big database.

- Many features such as principle line, wrinkles, ridges, minutiae points, singular points texture etc. are unique features in a palmprint image.
- Feature such as minutiae and singular points, ridges require high resolution images (400*dpi*) but principle line and wrinkles can be obtained from low resolution images (100*dpi*).
- It is difficult to obtain a high recognition rate using only principle lines due to their similarity across subject.

PALMPRINT (Palm Code - 2003)[13]

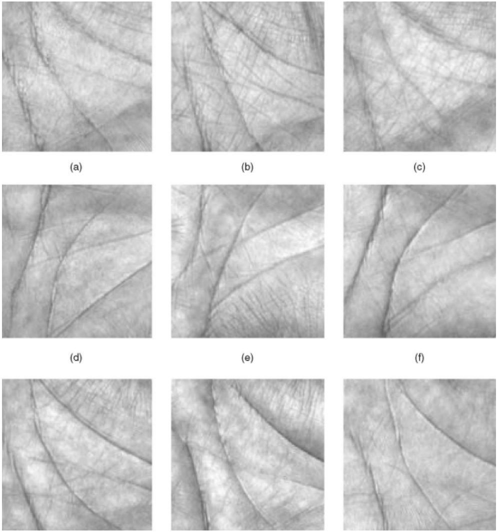
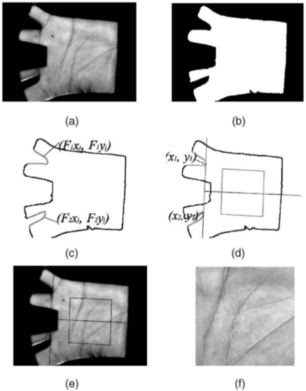


Figure: Row wise similar Principle line Palmprint images

PALMPRINT (Palm Code - 2003)[13]

- STEP 1: Apply low pass filter then thresholding to get a binary image.
- STEP 2: Get Boundaries of the 2 gaps between the fingers and find a line tangent to both gap. Set Y axis and X axis.
- STEP 3: Extract sub image of fixed size based on the coordinate system.



PALMPRINT (Palm Code - 2003)[13]

- Extract texture features from low resolution images using circular gabor filter. Circular gabor filter is defined as:

$$G(x, y, \theta, \mu, \sigma) = \frac{1}{2\pi\sigma^2} * e^{-(\frac{x^2+y^2}{2\sigma^2})} * e^{\{2\pi i(\mu x cos(\theta)+\mu y sin(\theta))\}} \tag{2}$$

  where $\mu = 0.0916$ is the frequency of sinusoidal wave, $\sigma = 5.6179$ is the standard deviation of the Gaussian envelop and $\theta = \frac{\pi}{4}$ controls the orientation of the function.

- DC component should be removed to make it robust against brightness defined as:

$$DC = \sum_{i=-n}^{n} \sum_{j=-n}^{n} \frac{G(i, j, \theta, \mu, \sigma)}{(2n+1)^2} \tag{3}$$

  for filter of size $(2n+1) \times (2n+1)$.

PALMPRINT (Palm Code - 2003)[13]

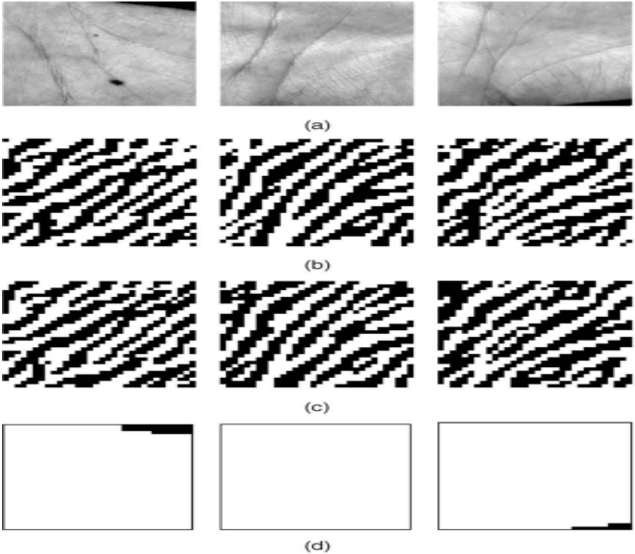


Figure: (a)Original (b)Real Part (c)Imaginary Part(d) Corresponding Mask

PALMPRINT (Palm Code - 2003)[13]

- Normalized Hamming distance is used as degree of similarity defined as:

$$D = \frac{\sum_{i=1}^{N}\sum_{j=1}^{N} P_M(i,j) \cap Q_M(i,j) \cap (P_R(i,j) \otimes Q_R(i,j)) + P_M(i,j) \cap Q_M(i,j) \cap (P_I(i,j) \otimes Q_I(i,j))}{2\sum_{i=1}^{N}\sum_{j=1}^{N} P_M(i,j)Q_M(i,j)} \quad (4)$$

where $P_R, Q_R =$ real part, $P_I, Q_I =$ imaginary part, $P_M, Q_M =$ mask.

PALMPRINT (Competitive Code - 2004)[8]

- Competitive code uses multiple 2D gabor filter to extract orientation information from palm lines and store it in a feature vector called Compcode. Angular matching is used for matching.
- Gabor filter is used to extract texture information based on Neuro physical evidences from visual cortex of mammalian brain and wavelet theory. Gabor is reform by Lee [8] as:

$$\phi(x, y, \omega, \theta) = \frac{\omega}{\sqrt{2\pi}\kappa} * e^{\frac{\omega^2}{8\kappa^2}(4x'^2 + y'^2)} * (e^{i\omega x'} - e^{-\frac{\kappa^2}{2}}) \tag{5a}$$

where (x_0, y_0) is the center of the function, ω is the radial frequency, θ is the orientation of the function and :

$$x' = (x - x_0)cos(\theta) + (y - y_0)sin(\theta) \tag{6}$$

$$y' = -(x - x_0)sin(\theta) + (y - y_0)cos(\theta) \tag{7}$$

D

PALMPRINT (Competitive Code - 2004)[8]

- The phase of the response is robust to contrast and brightness of the capturing device.

Competitive Rule: Winners Take All

$$Phase(x, y) = ArgMin_j(I(x, y) * \phi_R(x, y, \omega, \theta_j)) \tag{8a}$$

where

$$\phi_R = Real\ part\ of\ \phi \tag{8b}$$

$$\theta_j = \frac{j\pi}{6}\ is\ the\ orientation\ of\ the\ filter\ \{j \in (0 \ldots 5)\} \tag{8c}$$

- Apply Competitive rule to code each point to obtain the feature vector (*i.e.* Compcode).
- Compcode are highly related to the line features especially for strong lines such as principle lines

PALMPRINT (Competitive Code - 2004)[8]

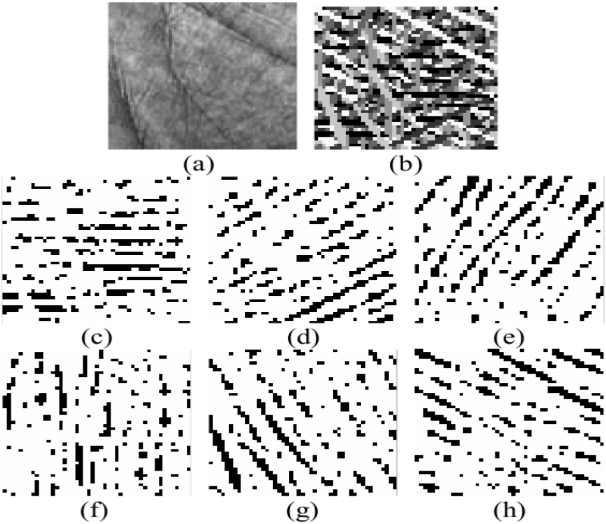
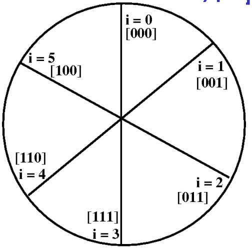


Figure: (a) Original (b) Compcode (c-h) Winners code for $j = 0 \ldots 5$

PALMPRINT (Competitive Code - 2004)[8]

ANGULAR MATCHING : It is required as distance between 0 *to* 5 should have to be less than 0 *to* 3.



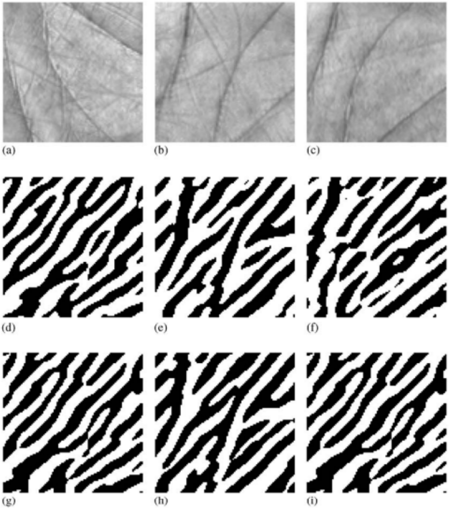
$$D(P,Q) = \frac{\sum_{y=0}^{N}\sum_{x=0}^{N}\sum_{i=1}^{3}(P_M(x,y)\cap Q_M(x,y))\cap(P_i(x,y)\otimes Q_i(x,y))}{3\sum_{y=0}^{N}\sum_{x=0}^{N}(P_M(x,y)\cap Q_M(x,y))} \tag{9}$$

where P_i and Q_i are the i^{th} bit plane and P_M and Q_M are the masks of the respective Compcodes.

- Perfect matching leads angular distance equal to zero.
- Imperfect processing leads to translation and rotations. Therefore feature vector is translated horizontally and vertically (-2 to 2) and minimum value is retained.

PALMPRINT (Fusion Code - 2005)[7]

- Palmcodes have structural similarity such as many 45^0 streaks.
- Correlation is reduced by using a fusion rule to select one gabor filter for coding the phase information.
- Bank of elliptical gabor filters are used to extract the features which are finally merged into a single feature vector called FUSIONCODE.
- Matching is done using using normalized hamming distance (same as in PALMCODE).



PALMPRINT (Fusion Code - 2005)[7]

- Bank of ν elliptical Gabor filters at various orientations ($\theta_j = \frac{j\pi}{\nu}$ for $j \in 0, 1, \ldots \nu - 1$) is defined as:

$$G_j(x, y, \theta_j, \mu, \sigma, \beta) = \frac{1}{2\pi\sigma\beta} * e^{-\pi(\frac{x'^2}{\sigma^2} + \frac{y'^2}{\beta^2})} * e^{(2i\mu x')} \tag{10}$$

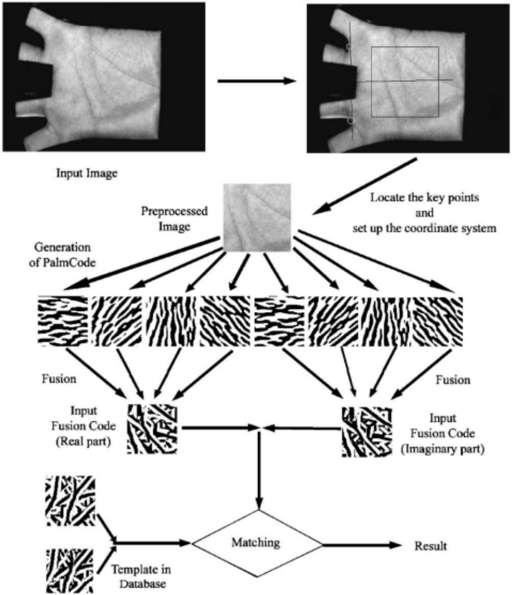
  where (x_0, y_0) is the center of the function and

$$x' = (x - x_0)cos(\theta_j) + (y - y_0)sin(\theta_j) \tag{11}$$
$$y' = -(x - x_0)sin(\theta_j) + (y - y_0)cos(\theta_j) \tag{12}$$

  Also, μ is the radial frequency of sinusoidal wave, σ and β are the standard deviation of the elliptical gausian envelop in x and y directions respectively.

- DC component should be removed to make it robust against brightness.

PALMPRINT (Fusion Code - 2005)[7]



PALMPRINT (Fusion Code - 2005)[7]

- Images filtered by G_j have 2 kinds of information:

$$[Magnitude] \quad M_j(x,y) = \sqrt{(G_j * I(x,y)) \times \overline{(G_j * I(x,y))}} \tag{13}$$

$$[Phase] \quad P_j(x,y) = \tan^{-1}\left(\frac{i[\overline{G_j * I(x,y)} - (G_j * I(x,y)]}{\overline{G_j * I(x,y)} + (G_j * I(x,y)}\right) \tag{14}$$

- Zero DC gabor filters makes Phase and magnitude independent of brightness of capturing device.
- Phase is also independent of the contrast of the image.

PALMPRINT (Fusion Code - 2005)[7]

Fusion Code Strategy

- Use that gabor to code the phase which has the maximum magnitude response (MAX Rule).

$$k = argmax_j \; (M_j(x, y)) \tag{15}$$

- Phase Encoding Table (h_r and h_i are bits for real and imaginary part of the fusion code.):

$$(h_r, h_i) = (1, 1) \quad if \; 0 \leq P_k(x, y) < \frac{\pi}{2} \tag{16}$$

$$(h_r, h_i) = (0, 1) \quad if \; \frac{\pi}{2} \leq P_k(x, y) < \pi \tag{17}$$

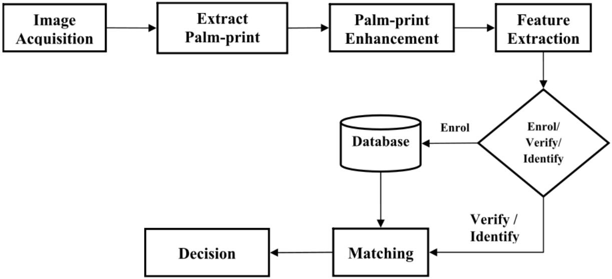
$$(h_r, h_i) = (0, 0) \quad if \; \pi \leq P_k(x, y) < \frac{3\pi}{2} \tag{18}$$

$$(h_r, h_i) = (1, 0) \quad if \; \frac{3\pi}{2} \leq P_k(x, y) < 2\pi \tag{19}$$

- Normalized Hamming distance is used for matching.

PALMPRINT (Phase Difference Information - 2011)[3]

- Phase difference information of local region is used as features which is extracted for several overlapping good blocks of Palmprint image.
- Reconstruction error through PCA is used to classify the block into good or bad.
- Matching between corresponding good blocks is done using hamming distance. 200*dpi* gray images are acquired from pegs free device.
- Finally weighted sum rule is used to fuse the scores obtained for each block to get an overall score. Weight given to each block considering the average discrimination level.



PALMPRINT (Phase Difference Information - 2011)[3]

PalmPrint Extraction

- Global Thresholding is applied to get binary image on to which contour tracing algorithm is applied to get the contour of hand.
- Left and rightmost points (X_1, X_2) are calculated and search local minimum on upper contour between X_1 and X_2 to get valley points (V_1, V_2, V_3, V_4).

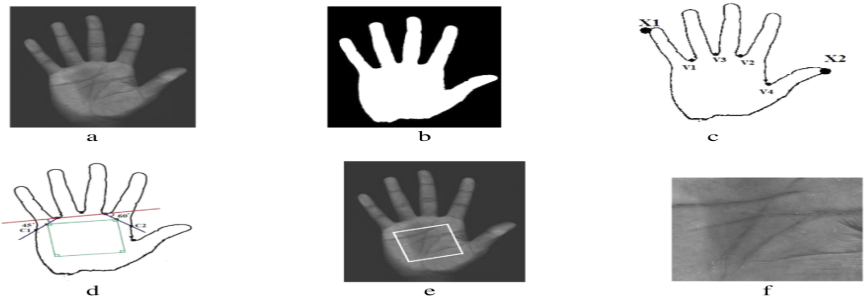


Figure: Palmprint Extraction

PALMPRINT (Phase Difference Information - 2011)[3]

PalmPrint Enhancement

- Extracted Palmprint is divided into blocks of size 32×32 or 16×16 and mean of each block is computed.
- Estimated reflection is scaled to original palmprint size and subtracted from the original image to get the uniform brightness image.
- Local histogram equalization is performed using 64×64 block size.

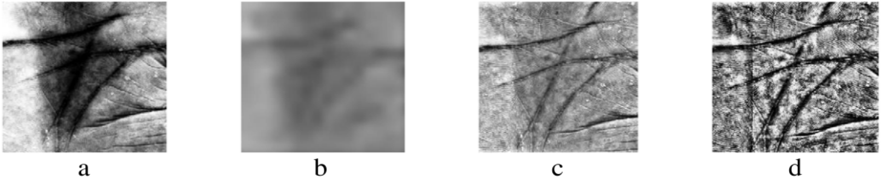


Figure: Palmprint Enhancement

PALMPRINT (Phase Difference Information - 2011)[3]

- Overlapping blocks are considered to have block area equally shared among all of them.
- Features from all the blocks are computed and concatenated to get a single compact feature vector.
- Number of Features for image and window sizes as $M \times M$ and $W \times W$ are $N^2 + (N-1)^2$ where $N = \frac{M}{W}$.

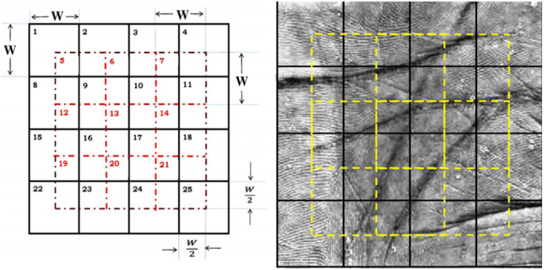
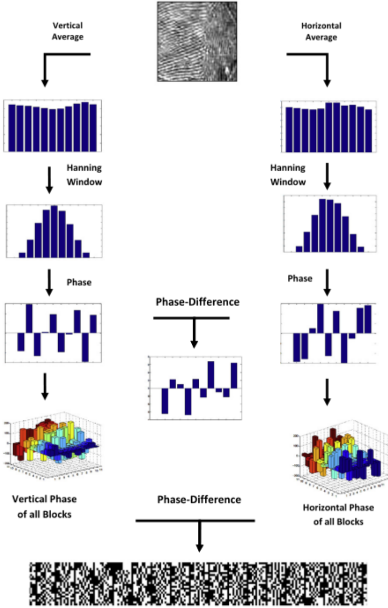


Figure: Palmprint Blocking Structure

PALMPRINT (Phase Difference Information - 2011)[3]

- Average blocks across the horizontal and vertical direction to obtain 1D signal of length W.
- After windowing obtain the Fourier Transform to get 1D phase.
- Phase difference between horizontal and vertical phase is binarised using zero crossing is treated as a W bit feature for each good block.
- Feature vector for all good blocks are concatenated to get the feature vector of the Palmprint.
- Good blocks are matched with corresponding good block.



PALMPRINT (Phase Difference Information - 2011)[3]

- Principle Components PC_p and PC_{np} are computed from a set of Palmprint images as well as Non Palmprint images respectively.
- Live palmprint block L_i is projected and reconstructed using PC_p to obtain R_p^i and using PC_{np} to obtain R_{np}^i.
- Reconstruction errors are defined as:

$$\xi_p^i = \|R_p^i - L_i\| \tag{20}$$

$$\xi_{np}^i = \|R_{np}^i - L_i\| \tag{21}$$

- Block Classification is done as:

$$L_i = \begin{cases} GOOD & if\ \xi_p^i < \xi_{np}^i \\ BAD & otherwise \end{cases}$$

PALMPRINT (Phase Difference Information - 2011)[3]

- Feature vector matrix is of size $K \times W$ where $K = N^2 + (N-1)^2$.
- Matching 2 feature vector matrix $L = l_1 \dots l_K$ and $E = e_1 \dots e_K$ as:

Non-Weighted fusion

$$HD = \frac{\sum_{i=1}^{K} \left(\sum_{p=1}^{W} \frac{l_i(p) \otimes e_i(p)}{W} \right)}{\#\ Good\ Blocks} \tag{23}$$

Weighted fusion

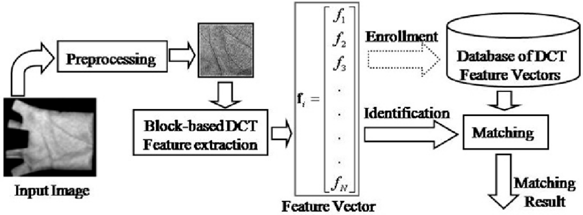
- Rich texture blocks can be more discriminative hence associating some weights to them.
- Average similarity distance (S_i) per block is calculated. (Matching is done within subject).
- Average dis-similarity distance (DS_i) per block is calculated. (Matching is done with other subject).
- Normalized value of $\|S_i - DS_i\|$ is used as discriminative level of block i.

PALMPRINT (DCT Features - 2009)[4]

- Features are extracted using DCT on small non overlapping blocks of segmented ROI as it represents image in few coefficients.
- Classification is done using euclidean distance.
- Input is the gray Palmprint scanned bitmap at $75dpi$ and (384×284).
- ROI of size (128×128) is extracted and preprocessed.
- DCT coefficients are calculated from the extracted image using 8×8 and 16×16 window sizes. Finally, ranking in done to extract *Top* half that are concatenated to get compact feature.

PALMPRINT (DCT Features - 2009)[4]

- Features are extracted using DCT on small non overlapping blocks of segmented ROI as it represents image in few coefficients.
- Classification is done using euclidean distance.
- Input is the gray Palmprint scanned bitmap at 75*dpi* and (384×284).
- ROI of size (128×128) is extracted and preprocessed.
- DCT coefficients are calculated from the extracted image using 8×8 and 16×16 window sizes. Finally, ranking in done to extract *Top* half that are concatenated to get compact feature.



PALMPRINT (DCT Features - 2009)[4]

Block DCT Feature Extraction

- The 2D-DCT, $C(u, v)$ of an image $I(r, c)$ of size $N \times N$ is defined as:

$$C(u,v) = \alpha(u)\alpha(v) \sum_{r=0}^{N-1} \sum_{r=0}^{N-1} I(r,c) * cos\left[\frac{(2r+1)u\pi}{2N}\right] * cos\left[\frac{(2c+1)v\pi}{2N}\right] \tag{24}$$

where $\alpha(u)$ and $\alpha(v)$ are given as:

$$\alpha(u), \alpha(v) = \begin{cases} \sqrt{\dfrac{1}{N}} & for \ u, v \ = \ 0 \\ \sqrt{\dfrac{2}{N}} & for \ u, v \ = \ 1, 2 \ldots N-1 \end{cases}$$

PALMPRINT (DCT Features - 2009)[4]

- Vector of size L is obtained from all of the M blocks by extracting the DCT coefficients and retaining the largest 50% based on magnitude.
- Each image is hence represented as a feature matrix of size $L \times M$.

Matching

- Score between 2 images a and b is defined as:

$$D = \sum_{i=1}^{M} \sqrt{\sum_{j=1}^{L} (a_{ij} - b_{ij})^2} \tag{26}$$

where M is the blocks per image and L is the length of the feature vector per block.

PALMPRINT (DCT Features - 2011)[2]

- Palmprint Image acquisition, extraction, enhancement and matching all remain to be the same as in the previous paper. Only the feature extraction method is different.
- Features are extracted using DCT-II to obtain good inter-class separation in minimum time. DCT-II is used as it can be applied to real value sequences and has strong compaction property. DCT-II coefficients are defined as:

$$CT_k = \frac{2}{N} w(k) \sum_{n=0}^{N-1} x_n * cos\left[\frac{\pi}{N}\left(n + \frac{1}{2}\right) k\right], \forall k \in \{0, 1 \ldots N-1\} \tag{27}$$

where x_n is a real valued sequence of length N and $w(k)$ is defined as:

$$w(k) = \begin{cases} \frac{1}{\sqrt{2}} & if \;\; k \;=\; 0 \\ 1 & otherwise \end{cases}$$

PALMPRINT (DCT Features - 2011)[2]

- DCT transformation of larger images has better energy compaction but for smooth regions. Palmprint images are textured images hence require to be divided into sub images.
- Fixed sized blocking may also not provide good feature variation.
- DCT on overlapping rectangular blocks of variable size and orientations are considered for extracting good features (parameters are optimized for performance).

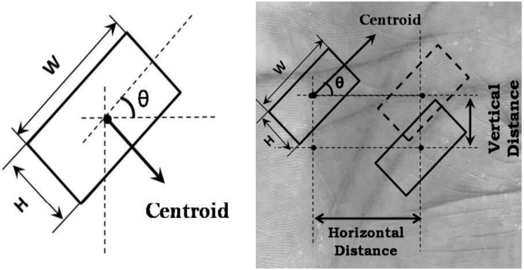


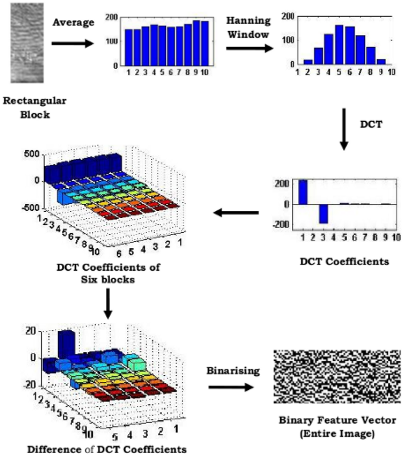
Figure: Palmprint Blocking Structure

PALMPRINT (DCT Features - 2011)[2]

- The segmented oriented rectangular block (R) of size $W \times H$ is averaged across its height to obtain 1D intensity signal ($\mathbb{R}_j$) of width W defined as:

$$\mathbb{R}_j = \sum_{k=1}^{H} R_{j,k}, \ \forall j \in \{1, 2 \dots W\} \quad (29)$$

- Signal $\mathbb{R}$ is windowed using hanning window and then DCT coefficients are computed.
- Difference of DCT coefficients from each vertically adjacent block are computed.
- The difference is finally binarized using zero crossing.



PALMPRINT (DCT Features - 2011)[2]

	IITK	CASIA	PolyU
Vertical Distance	13	10	11
Horizontal Distance	21	18	12
Height	20	16	16
Width	32	24	20
Angle	45°	45°	45°

	CRR (%)	EER (%)	DI
Palm-code [22]	99.9168	0.5338	5.5807
Ordinal code [27]	100.000	0.0709	6.6785
Kipsang et. al., [51]	85.848	20.113	0.7988
Dale et. al., [52]	90.904	11.904	2.2692
Proposed	**100.00**	**0.0333**	**7.7501**

	Extraction (ms)	Matching (ms)	Total (ms)
Palm-code [22]	54.4166	0.73156	55.1482
Ordinal code [27]	155.1370	2.3652	157.5022
Kipsang et. al.,[51]	14.4190	0.4813	14.9003
Dale et. al., [52]	5.3010	0.0100	5.3110
Proposed	**48.9695**	**0.4988**	**49.4683**

Figure: Results : (a)Optimal Parameters (b)Performance (c) Timing

IRIS Based PAS

- **An Effective Approach for Iris Recognition Using Phase-Based Image Matching**
  Miyazawa, Kazuyuki, Ito, Koichi, Aoki, Takafumi, Kobayashi, Koji, and Nakajima, Hiroshi
  IEEE Trans. Pattern Anal. Mach. Intell. 30(10), volume 30, 17411756, 2008.
- **Iris Recognition on Edge Maps**
  Sudha, N., Puhan, N.B., Xia, Hua, and Jiang, Xudong
  6th International Conference on Information Communications Signal Processing 2007 , volume , 1-4, dec. 2007.
- **Iris Recognition Based on Multichannel Gabor Filtering**
  Ma, Li, Wang, Yunhong, and Tan, Tieniu
  Proceedings of the International Conference on Asian Conference on Computer Vision, 279283, 2002
- **On the Fusion of Periocular and Iris Biometrics in Non-ideal Imagery**
  Woodard, D.L., Pundlik, S., Miller, P., Jillela, R., and Ross, A.
  Pattern Recognition (ICPR), 2010 20th International Conference on, volume , 201204, aug. 2010

IRISCODE (BLPOC - 2008)[10]

- Problems in feature based iris recognition
  - Matching performance depends on several parameters such as, spatial position, orientation, 2D gabor filter kernels parameters.
  - Extensive parameter optimization is required to achieve high recognition rates.
- Proposed phase components in 2D-DFT for iris recognition.
- Same technique is used for fingerprint recognition in their previous work.
- Tested over
  - CASIA iris images database (v1 and v2).
  - (ICE) Iris Challenge Evaluation 2005 database.

IRISCODE (BLPOC - 2008)[10]

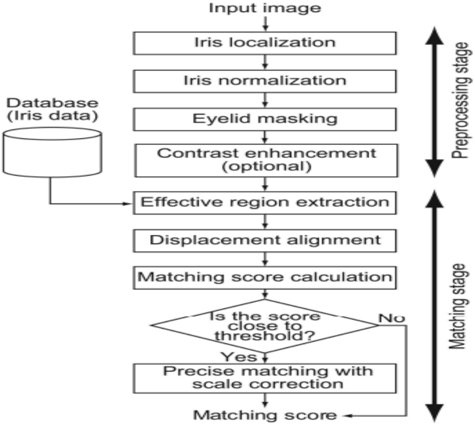


Figure: Flow diagram of algorithm

IRISCODE (BLPOC - 2008)[10]

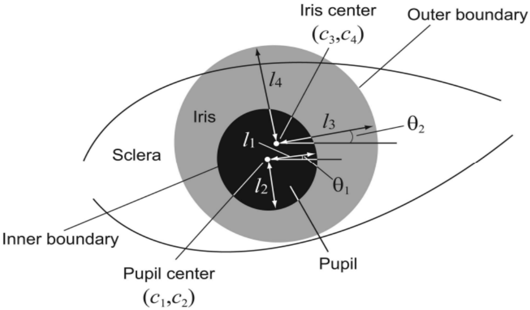


Figure: Deformable Iris model

- 10 parameters are used to represent iris in its the most general form.
- Pupil ellipse $\{l1, l2, c1, c2, \theta1\}$
- Iris ellipse $\{l3, l4, c3, c4, \theta2\}$

D

IRISCODE (BLPOC - 2008)[10]

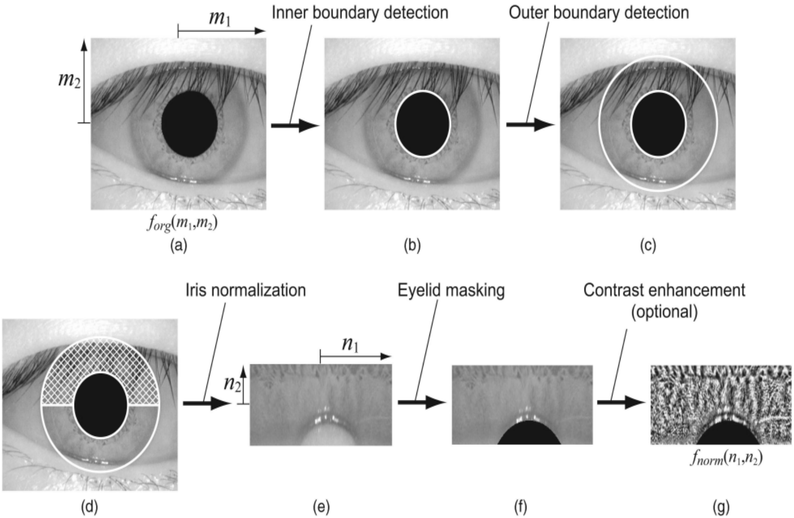


Figure: Iris image preprocessing

IRISCODE (BLPOC - 2008)[10]

Let f and g are $M \times N$ images such that $m = -M_0 ... M_0 (M_0 > 0)$ and $n = -N_0 ... N_0 (N_0 > 0)$ Also $M = 2M_0 + 1$ and $N = 2N_0 + 1$

$$F(u,v) = \sum_{m=-M_0}^{M_0} \sum_{n=-N_0}^{N_0} f(m,n) e^{-j2\pi(\frac{mu}{M} + \frac{nv}{N})} = A_F(u,v) e^{j\theta_F(u,v)} \tag{30a}$$

$$G(u,v) = \sum_{m=-M_0}^{M_0} \sum_{n=-N_0}^{N_0} g(m,n) e^{-j2\pi(\frac{mu}{M} + \frac{nv}{N})} = A_G(u,v) e^{j\theta_G(u,v)} \tag{30b}$$

(30c)

Cross Phase Spectrum $R_{GF}(u,v)$ between G and F is defined as:

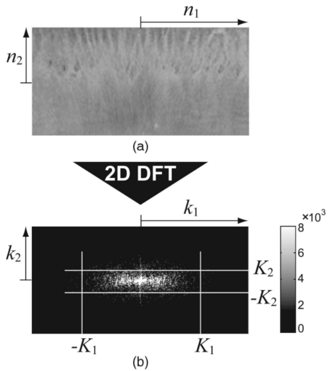
$$R_{GF}(u,v) = \frac{G(u,v) \times F^*(u,v)}{|G(u,v) \times F^*(u,v)|} = e^{j(\theta_G(u,v) - \theta_F(u,v))} \tag{30d}$$

POC (Phase Only Correlation) $P_{gf}(m,n)$ is the 2D Inverse DFT (IDFT) of the above defined as:

$$P_{gf}(m,n) = \frac{1}{MN} \sum_{u=-M_0}^{M_0} \sum_{v=-N_0}^{N_0} R_{GF}(u,v) e^{j2\pi(\frac{mu}{M} + \frac{nv}{N})} \tag{30e}$$

IRISCODE (BLPOC - 2008)[10]

- If f and g images are similar POC function gives a distinct sharp peak else peak value drop significantly.
- Hence, Height of the peak value is used as similarity measure.
- Some meaning less high frequencies prone to noise reduces the height of the correlation peaks.
- Effective frequency band is wider in horizontal direction than in vertical.



IRISCODE (BLPOC - 2008)[10]

- BLPOC function allows us to evaluate the similarity by using the inherent frequency band of the iris texture.
- Let inherent frequency band of iris texture is $m = -k_1 ... k_1 (k_1 > 0)$ and $n = -k_2 ... k_2 (k_2 > 0)$.
- Effective size of the frequency band spectrum is $L_1 = 2K_1 + 1$ and $L_2 = 2K_2 + 1$. BLPOC is defined as:

$$P_{gf}(m, n) = \frac{1}{L_1 L_2} \sum_{u=-k_1}^{k_1} \sum_{v=-k_2}^{k_2} R_{GF}(u, v) e^{j2\pi(\frac{mu}{L_1} + \frac{nv}{L_2})} \qquad (31)$$

- BLPOC exhibits a higher correlation peak than that of the original POC function hence provides much higher discrimination capability than the original POC function.

IRISCODE (HD on Edgemap - 2007)[11]

- Hausdroff distance is proposed to discriminate binary edge maps of the iris images.
- Edge maps requires low storage space and can be processed very fast also can be transmitted very fast. Provides some robustness to illumination variations.
- Partial Hausdroff distance is used on UPOL iris database.

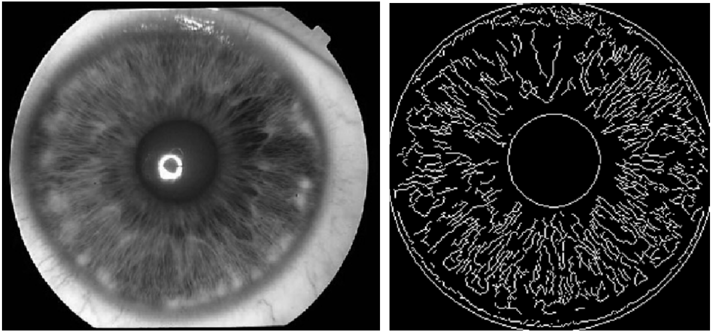


Figure: Sample and Edgemap iris images

IRISCODE (HD on Edgemap - 2007)[11]

- Let A, B be two Set of points. Hausdorff distance [6] is defined as:

$$HD(A,B) = HD(B,A) = max(hd(A,B), hd(B,A))$$

here *hd(A,B)* is the directed Hausdorff distance defined by:

Directed hd

$$hd(A,B) = \max_{a \in A} \min_{b \in B} \|a - b\|$$

- Partial Hausdroff distance PHD is defined as:

$$PHD(A,B) = PHD(B,A) = max(phd(A,B), phd(B,A))$$

here *phd(A,B)* is the directed PHD, which is defined by:

Directed phd

$$phd(A,B) = K^{th} \max_{a \in A} \min_{b \in B} \|a - b\|$$

and, $\|.\|$ is the norm of the vector.

IRISCODE (HD on Edgemap - 2007)[11]

- Directed Modified Hausdroff distance *MHD* is defined as:

$$mhd(A,B) = \frac{1}{N_a} \sum_{a \in A} \min_{b \in B} \|a - b\|$$

Where N_a is the number of points in set A.

- *MHD* is improved to *M2HD* [1] by adding 3 more parameters :
  Neighborhood function ($\boldsymbol{N_B^a}$) N'hood of the point a in set B
  Indicator variable (I) $I = 1$ if a's corresponding point lie in N_B^a else $I = 0$
  Associated penalty (P) if $I = 0$ penalize with this penalty
  and directed *M2HD* is defined as:

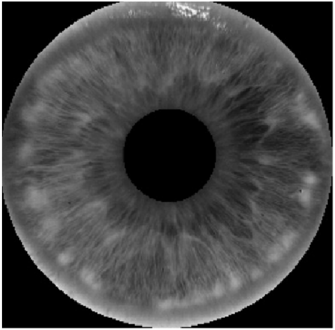
$$m2hd(A,B) = \frac{1}{N_a} \sum_{a \in A} d(a,B)$$

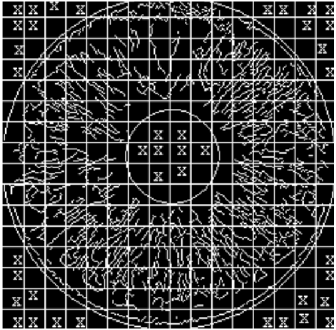
Where *d(a,B)* is defined as:

$$d(a,B) = \max[(I \cdot \min_{b \in N_B^a} \|a - b\|), ((1 - I) \cdot P)]$$

IRISCODE (HD on Edgemap - 2007)[11]

- Iris images are segmented by applying circular Hough transform on the edge maps generated using Canny edge detector. Binary edge maps are normalized to 256×256 pixels.
- Normalized segmented image is divided in to blocks and PHD and MHD are calculated only between the significant blocks at identical position. Finally scores for all of the blocks are added and normalized to get dissimilarity score. [64×64 block size performs best]





IRISCODE (Multichannel Gabor Filtering - 2002)[9]

- Features are extracted using a bank of gabor filters because iris has abundant texture information.
- Fixed length feature vectors are matched using weighted euclidean distance for fast matching.

PREPROCESSING

Iris localization : Done using edge detection and Hough transform.

Iris normalization : Done by unwrapping iris ring to a rectangular block of fixed size 64×512. Further for feature extraction it is divided into 8 blocks of 64×64.

Enhancement : De noising the high frequency noise by filtering with a low pass Gaussian filter. Local histogram equalization is performed in order to deal with low contrast and non-uniform illumination.

IRISCODE (Multichannel Gabor Filtering - 2002)[9]

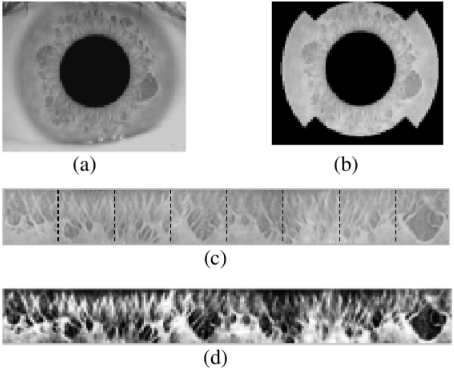


Figure: (a) Original (b) Localized (c) Unwrapped (d) Enhanced

- Filter 8 sub images separately using these 20 gabor filters corresponding to 5 central frequencies as $f = 2, 4, 8, 16, 32$ and 4 different orientations as $\theta = 0^0, 45^0, 90^0, 135^0$. This leads to generate 160 output images.

IRISCODE (Multichannel Gabor Filtering - 2002)[9]

- Average Absolute Deviation (AAD) is considered as the feature values for each of the output image defined as:

$$V = \frac{1}{N}(\sum_{N} |f(x, y) - m|) \tag{32}$$

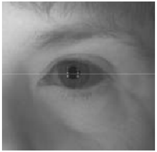
  here m is the mean of the image and N is the number of pixel in the image $f(x, y)$.
- Feature Vector : AAD of each 160 output images constitute the components of 1D - feature vector of length 160.
- Feature Matching : Weighted Euclidean Distance (WED) is computed between feature vector defined as:

$$WED(k) = \sqrt{\sum_{i=1}^{BN} A_i \sum_{j=1}^{N} (f_{(i,j)}^{k} - f_{(i,j)})^2} \tag{33}$$

  BN and N are number of subimages and features and A_i is fixed emperically.
- Nearest neighbour classifier is used.
- Rotation invariance is obtained by unwrapping the iris ring at different initial angles as $(-10^0, -5^0, 0^0, 5^0, 10^0)$.

IRISCODE (Periocular and Iris Fusion - 2010)[12]

- Iris based systems are severely impacted by non ideal iris images including occlusion motion or spatial blur poor contrast, specular reflection and illumination.
- Factors regulating the achievable accuracy are:
  - Quality of image.
  - Spatial extent of the iris present in the captured image.
- Reliability of iris data can be improved by fusing it with information from the surrounding region called periocular region considered as soft biometrics.
- Periocular encompasses eyelids, eyelashes, eyebrows and neighboring skin area. Also it requires no additional sensors.



IRISCODE (Periocular and Iris Fusion - 2010)[12]

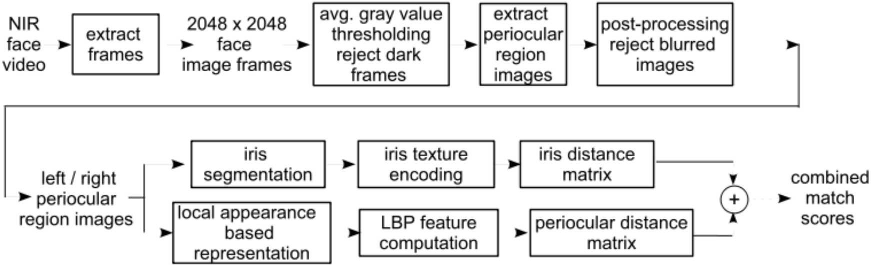
DATASET: Images are taken from Near Infra-Red face videos of the Multi Biometric Grand Challenge database (MBGC). Videos are in avi format and 2048 resolution with iris spatial extent of just 120 pixels.

- Fixed size (601×601) periocular region is cropped manually. Finally iris and periocular textural patterns are extracted.
- Iris recognition is done using Daugman approach and for periocular region they have used local binary patterns (LBP).
- IRIS LOCALIZATION : Done using integro-differential operator defined as:

$$max_{(r,x_0,y_0)} \left| G_\sigma(r) * \frac{\partial}{\partial r} \oint_{(r,x_0,y_0)} \frac{I(x,y)}{2\pi r} \mathrm{d}s \right| \tag{34}$$

Operator behaves as a circular edge detector.

IRISCODE (Periocular and Iris Fusion - 2010)[12]



IRISCODE (Periocular and Iris Fusion - 2010)[12]

J. Daugman (93) Approach[5]

- Segmentation is performed to separate iris from noise region such as eyelashes, eyelids, pupil and specular regions. It is performed manually.
- Normalization is done by unwrapping segmented iris onto normalized polar coordinate system.
- Textural features are extracted by convolving 2D gabor filter with unwrapped iris image. Phaser output is encoded as a matrix of bits known as IRISCODE.
- Normalized Hamming distance is used to measure the dissimilarity.

IRISCODE (Periocular and Iris Fusion - 2010)[12]

Periocular Skin Texture (LBP)

- Local Binary Patterns (LBP) are used to quantify commonly observed intensity patterns in a local pixel neighborhood patches such as spot, line ends, edges, corners and other distinct texture patterns.
- Periocular skin texture is divided into blocks and features are computed locally.
- Interior eye regions are masked with an ellipse of fixed dimensions.
- LBP score for a pixel is computed wrt 8 neighborhood which is in turn encoded into a histogram of 59 bins ($i.e.\ 8 * 7 + 3$).
- Overall texture feature is represented as:

$$\tau(I) = \{T^1 \dots T^N\} \tag{35}$$

  where N is number of blocks and T^i is the texture histogram corresponding to the i^{th} block. $\tau(I)$ can be seen as a 1D vector of size $59 \times N$.
- City block metric is used to compare 2 vectors $\tau(I_1)$ and $\tau(I_2)$.

IRISCODE (Periocular and Iris Fusion - 2010)[12]

- Finally 2 matching scores are generated one from iris and other from periocular region.
- Scores are normalized using min max normalization scheme.
- Weighted Sum rule is used for score level fusion. Best matching performance is obtained with weights $[0.4, 0.6]$ given to iris and periocular biometrics respectively.

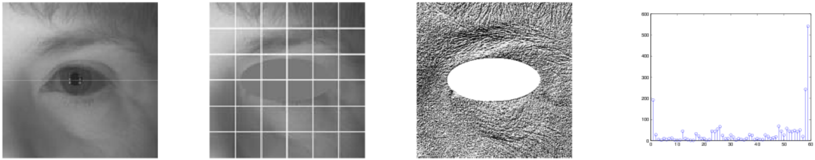


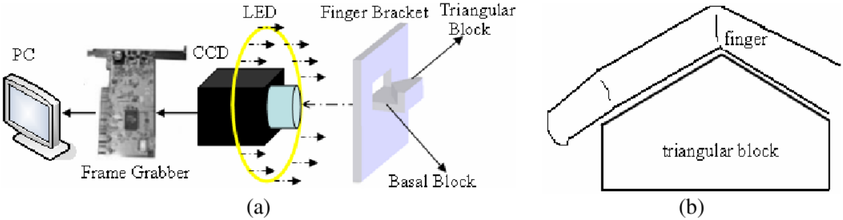
Figure: Periocular Recognition

KNUCKLEPRINT Based PAS

- **Finger Knuckle-Print Verification Based on Band-Limited Phase-Only Correlation**
  Zhang, Lin, Zhang, Lei, and Zhang, David
  Computer Analysis of Images and Patterns, volume 5702, Springer Berlin Heidelberg, 141-148, Eds: Jiang, Xiaoyi, and Petkov, Nicolai, 2009.
- **Finger Knuckle Print**
  A New Biometric Identifier
  Zhang, Lin, Zhang, Lei, and Zhang, David.
- **Online finger-knuckle-print verification for personal authentication**
  Zhang, Lin, Zhang, Lei, Zhang, David, and Zhu, Hailong
  Pattern Recogn. 43, volume 43, Elsevier Science Inc., 2560 - 2571, July 2010.

KNUCKLE (Global Feature BLPOC - 2009) [14]

- Novel FKP acquisition device is used to capture FKP image.
- Local Convex Direction (LCD) map is computed to define a reference coordinate system to register images and to extract a ROI for feature extraction and matching.
- FKP images are matched using *BLPOC* method exploiting the global features.



KNUCKLE (Global Feature BLPOC - 2009) [14]

ROI Extraction

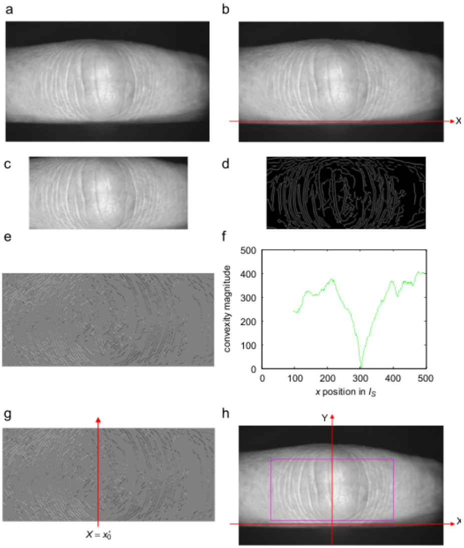
- STEP 1: Bottom Boundary is extracted using Canny and assigned as X-axis.
- STEP 2: Crop the original image using 3 empirically selected boundaries values.
- STEP 3: Apply Canny edge detector.
- STEP 4: Apply convex direction coding on edgemap. Every pixel have a code representing its convex direction.
- STEP 5: Convexity direction measures strength of dominant direction locally defined as: D

$$conMag(x) = |\sum_{W} I_{CD}| \qquad (36)$$

Curves along small area around phalangeal joint do not have obvious convex direction.

$$x_0 = argmin_x(conMag(x)) \qquad (37)$$

- STEP 6: Set $X = X_0$ as the Y-axis.



KNUCKLE (Global Feature BLPOC - 2009) [14]

- For feature extraction POC and BLPOC are used exactly in the same manner as in IRISCODE.
- Phase Only Correlation is defined as:

$$P_{gf}(m,n) = \frac{1}{MN} \sum_{u=-M_0}^{M_0} \sum_{v=-N_0}^{N_0} R_{GF}(u,v) e^{j2\pi(\frac{mu}{M}+\frac{nv}{N})} \tag{38}$$

- Band Limited Phase Only Correlation is defined as:

$$P_{gf}(m,n) = \frac{1}{L_1 L_2} \sum_{u=-k_1}^{k_1} \sum_{v=-k_2}^{k_2} R_{GF}(u,v) e^{j2\pi(\frac{mu}{L_1}+\frac{nv}{L_2})} \tag{39}$$

- BLPOC exhibits a higher correlation peak than that of the original POC function hence provides much higher discrimination capability than the original POC function.

KNUCKLE (Local Feature Gabor - 2009)

- Competitive code [8] is used for feature extraction and rest remained to be the same.
- Orientation information is extracted using a bank of gabor filters sharing same parameter except the orientations.
- Only real part of filter is used for feature extraction.

$$Compcode(x, y) = ArgMin_j(I_{ROI}(x, y) * G_R(x, y, \omega, \theta_j)) \tag{40a}$$

where

$$G_R = Real\ part\ of\ filter\ G \tag{40b}$$

$$\theta_j = \frac{j\pi}{6}\ is\ the\ orientation\ of\ the\ filter\ \{j \in (0 \ldots 5)\} \tag{40c}$$

- Angular matching is used for matching on extended dataset so as to achieve robustness towards translation.

KNUCKLE (ImCompcode and Magcode- 2010)[15]

- They combined both orientation and magnitude information for feature extraction using bank of gabor filters.
- Compcode is modified to ImCompCode and used along with MagCode.
- Angular distance is used for matching.
- Final score is obtained by fusing the results obtained by both *ImCompcode* and *MagCode* using weighted sum rule .
- Pixels on plain areas does not have a dominant orientation. Hence do not provide robust features.
- Such pixels do not have much variation in their gabor responses. They are detected and are not considered while coding the magnitude.

KNUCKLE (ImCompcode and Magcode- 2010)[15]

- *ImCompCode* is defined as:

$$Compcode(x, y) = ArgMin_j(I_{ROI}(x, y) * G_R(x, y, \omega, \theta_j)) \tag{41}$$

$$OriMag(x, y) = \frac{|max(R) - min(R)|}{max(|max(R)|, |min(R)|)} \tag{42}$$

  where R is a vector holding the gabor response for all 6 orientations of pixel (x, y).

- Orientation magnitude tells how likely the pixel (x, y) has a dominant orientation. *ImCompCode* is computed as:

$$ImCompCode(x, y) = \begin{cases} 6 & if \;\; OriMag(x, y) < T \\ ArgMin_j(R_j) & Otherwise \end{cases}$$

KNUCKLE (ImCompcode and Magcode- 2010)[15]

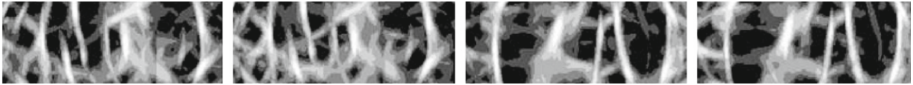
- MagCode is obtained by applying gabor filter's real part as:

$$mag(x,y) = Max_j(|I_{ROI}(x,y) * G_R(x,y,\omega,\theta_j)|) \tag{44}$$

locally quantized as:

$$MagCode(x,y) = \left\lceil \frac{mag(x,y) - L_{min}}{\frac{L_{max}-L_{min}}{QLevels}} \right\rceil \tag{45}$$

here L_{max} and L_{min} are the maximum and minimum magnitude among the pixels within a specified neighborhood (W).



Takacs B.
Comparing face images using the modified hausdorff distance.
Pattern Recognition, 31(13):1873 –1881, 1998.

G.S Badrinath and P Gupta.
An efficient palmprint based recognition system using dct features.
Pattern Recognition Letters, April 2011.

G.S Badrinath and P Gupta.
Palmprint based recognition system using phase-difference information.
In *Journal of Future Generation Computer Systems*, 2011.

H. Kipsang Choge, Tadahiro Oyama, Stephen Karungaru, Satoru Tsuge, and Minoru Fukumi.
Palmprint recognition based on local dct feature extraction.
In *Proceedings of the 16th International Conference on Neural Information Processing: Part I*, ICONIP '09, pages 639–648, Berlin, Heidelberg, 2009. Springer-Verlag.

J.G. Daugman.

High confidence visual recognition of persons by a test of statistical independence.
Pattern Analysis and Machine Intelligence, IEEE Transactions on, 15(11):1148 –1161, nov 1993.

D.P. Huttenlocher, G.A. Klanderman, and W.J. Rucklidge.
Comparing images using the hausdorff distance.
Pattern Analysis and Machine Intelligence, IEEE Transactions on, 15(9):850 –863, sep 1993.

Adams Kong, David Zhang, and Mohamed Kamel.
Palmprint identification using feature-level fusion.
Pattern Recogn., 39:478–487, March 2006.

Adams Wai-Kin Kong and David Zhang.
Competitive coding scheme for palmprint verification.
In *ICPR (1)*, pages 520–523, 2004.

Li Ma, Yunhong Wang, and Tieniu Tan.
Iris recognition based on multichannel gabor filtering.

In *Proceedings of the International Conference on Asian Conference on Computer Vision*, pages 279–283, 2002.

Kazuyuki Miyazawa, Koichi Ito, Takafumi Aoki, Koji Kobayashi, and Hiroshi Nakajima.
An effective approach for iris recognition using phase-based image matching.
IEEE Trans. Pattern Anal. Mach. Intell., 30(10):1741–1756, 2008.

N. Sudha, N.B. Puhan, Hua Xia, and Xudong Jiang.
Iris recognition on edge maps.
In *Information, Communications Signal Processing, 2007 6th International Conference on*, pages 1 –4, dec. 2007.

D.L. Woodard, S. Pundlik, P. Miller, R. Jillela, and A. Ross.
On the fusion of periocular and iris biometrics in non-ideal imagery.
In *Pattern Recognition (ICPR), 2010 20th International Conference on*, pages 201 –204, aug. 2010.

David Zhang, Adams Wai-Kin Kong, Jane You, and Michael Wong.
Online palmprint identification.

IEEE Trans. Pattern Anal. Mach. Intell., 25(9):1041–1050, 2003.

Lin Zhang, Lei Zhang, and David Zhang.
Finger-knuckle-print verification based on band-limited phase-only correlation.
In Xiaoyi Jiang and Nicolai Petkov, editors, *Computer Analysis of Images and Patterns*, volume 5702 of *Lecture Notes in Computer Science*, pages 141–148. Springer Berlin / Heidelberg, 2009. 10.1007/978-3-642-03767-2_17.

Lin Zhang, Lei Zhang, David Zhang, and Hailong Zhu.
Online finger-knuckle-print verification for personal authentication.
Pattern Recogn., 43:2560–2571, July 2010.

IRISCODE (BLPOC - 2008)[10]

- Start with a initial estimate and then find optimal estimate by maximizing the absolute difference :

$$|S(l_1 + \delta l_1, l_2 + \delta l_2, c_1, c_2, \theta_1) - S(l_1, l_2, c_1, c_2, \theta_1)| \tag{46}$$

  where S denotes the N-point contour summation of the pixel values along the ellipse.
- Inner boundary is detected as that ellipse fro which there is sudden change in the luminance summed around its perimeter.
- Reduce computation $\theta 1 = 0$ and $l_1 = l_2$ can be used.

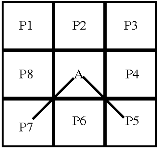
Back

KNUCKLE (Global Feature BLPOC - 2009) [14]

Convex Direction Coding

- Every point on the edgemap will be given a code to represent its local direction.
- Curve is either convex leftward $(+1)$ or convex rightward (-1). Rest pixels not on any curve given (0).

$$A_{code} = \begin{cases} 0 & \textit{If } (A = 0)\ [\textit{Not onCurve}] \\ 0 & \textit{ElseIf } (P_7 \& P_5)\ [\textit{BifurcationPoint}] \\ +1 & \textit{ElseIf } (P_7\ \&\ (A \in UH) || P_5\ \&\ (A \in LH))\ [\textit{Convex Left}] \\ -1 & \textit{ElseIf } (P_5\ \&\ (A \in UH) || P_7\ \&\ (A \in LH))\ [\textit{Convex Right}] \end{cases}$$



Back

PALMPRINT (Competitive Code - 2004)[8]

- (x_0, y_0) is the center of the function, ω is the radial frequency, θ is the orientation of the function and :

$$x' = (x - x_0)cos(\theta) + (y - y_0)sin(\theta) \tag{48}$$

$$y' = -(x - x_0)sin(\theta) + (y - y_0)cos(\theta) \tag{49}$$

$$\kappa = \sqrt{2 \ln 2} * \frac{2^\delta + 1}{2^\delta - 1} \tag{50}$$

$$\omega = \frac{\kappa}{\sigma} \tag{51}$$

here δ is the half amplitude bandwidth of frequency response (1 to 1.5).

Back

PALMPRINT (Fusion Code - 2005)[7]

Let 2 Gabor filters are applied on the original image.

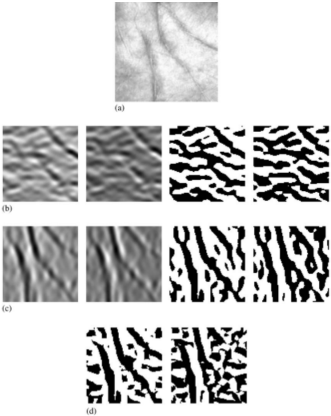


Figure: (a) Original (b-c) Column 1 Real and Column 2 Imaginary part of filtered image, Column 3 and 4 are Real and Imaginary parts of PalmCode (d) Real and Imaginary parts of FusionCode

Back