Algorithms for Recognition of Low Quality Iris Images

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Overview

- Iris Recognition
- Eyelash detection
- Accurate circular localization
- Covariance feature with LDA
- Fourier magnitude feature
- Progressive segmentation
- Conclusion

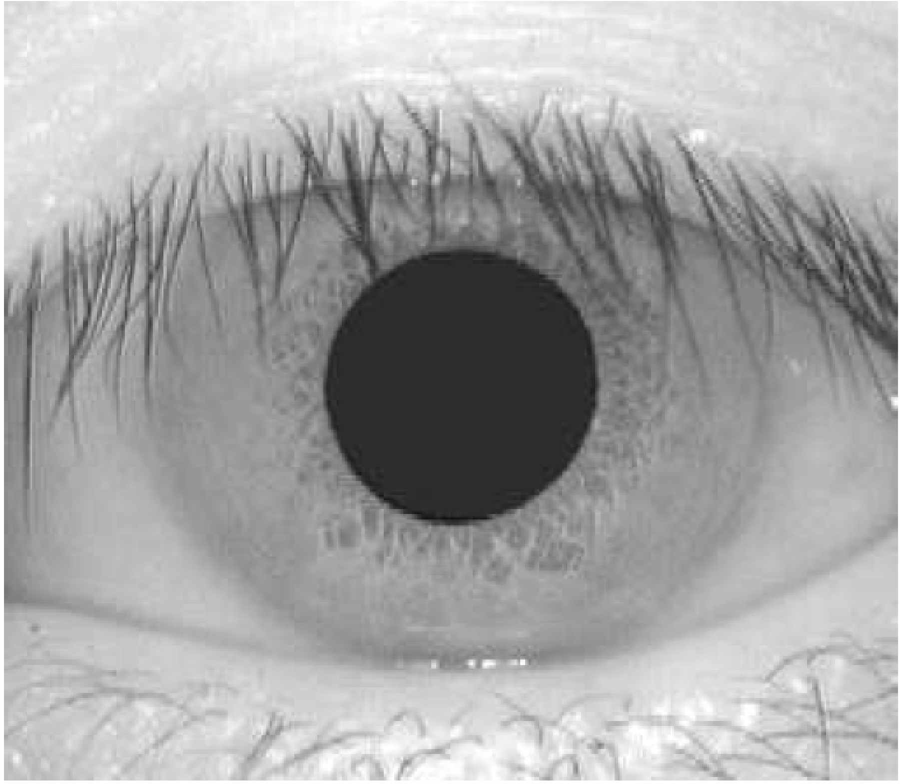
Iris Recognition System

- Image acquisition
- Segmentation
- Representation
- Feature extraction
- Pattern Matching

Problems and Proposed Solutions

- Problems:
  - Low-quality iris image: eyelash occlusion
  - Rotational Compensation
- Solutions:
  - Improved accuracy in segmentation
    - Eyelash detection
    - Circular localization
  - Rotational invariant feature extraction
    - Covariance feature
    - Fourier Magnitude feature

Eyelash Occluded Image

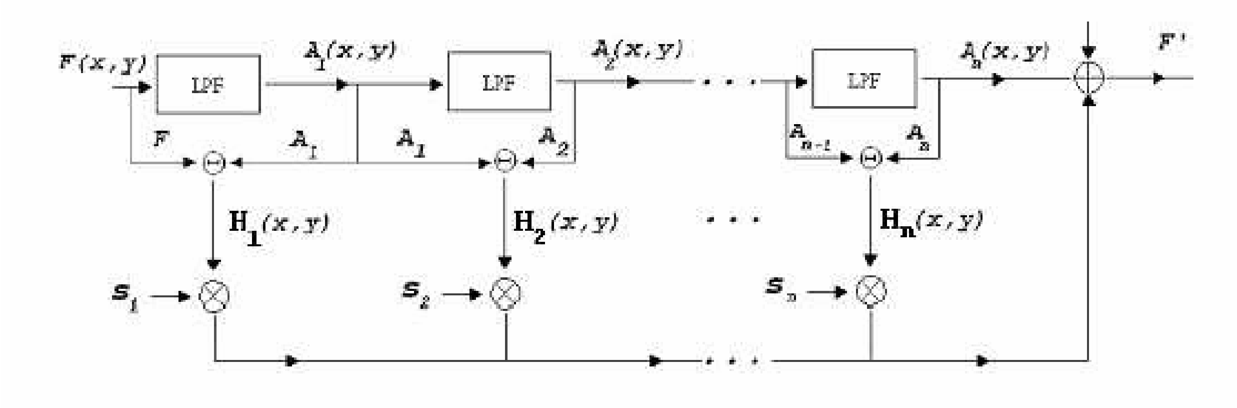


Eyelash detection algorithm

- Image smoothing

$$\psi(F) = log((255 - F)/F)$$

- Image enhancement



Separable eyelash detection

- Kernel masks for various directions

-1	-1	-1
2	2	2
-1	-1	-1

-1	2	-1
-1	2	-1
-1	2	-1

2	-1	-1
-1	2	-1
-1	-1	2

-1	-1	2
-1	2	-1
2	-1	-1

- Convolution

$$R_i(x, y) = \sum_{m=-N}^{N} \sum_{n=-N}^{N} I(x - m, y - n) M(m, n)$$

- Thresholding
- Connective Criterion

Multiple eyelashes detection

- Local statistics

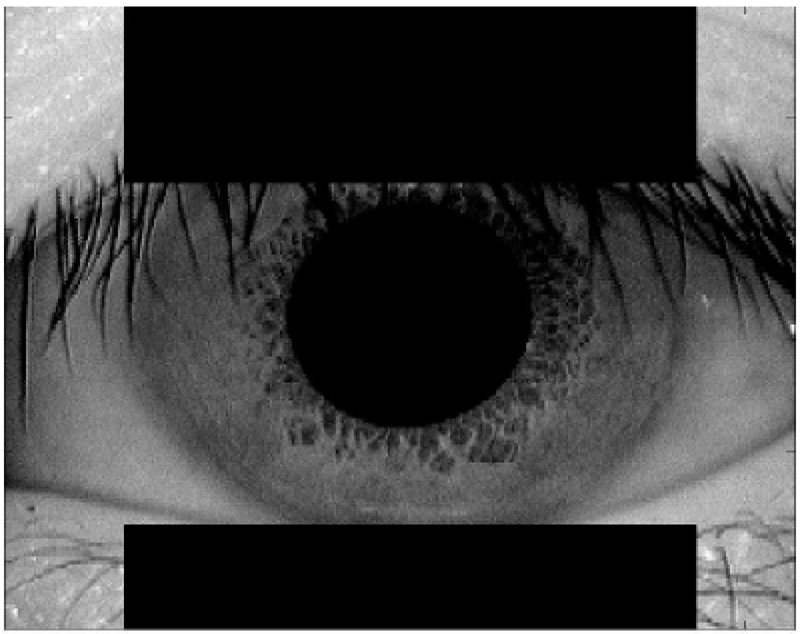
$$u_{bi}(x,y) = \frac{1}{n^2}\sum_{i=-n}^{n}\sum_{j=-n}^{n} f(x+i, y+j)$$

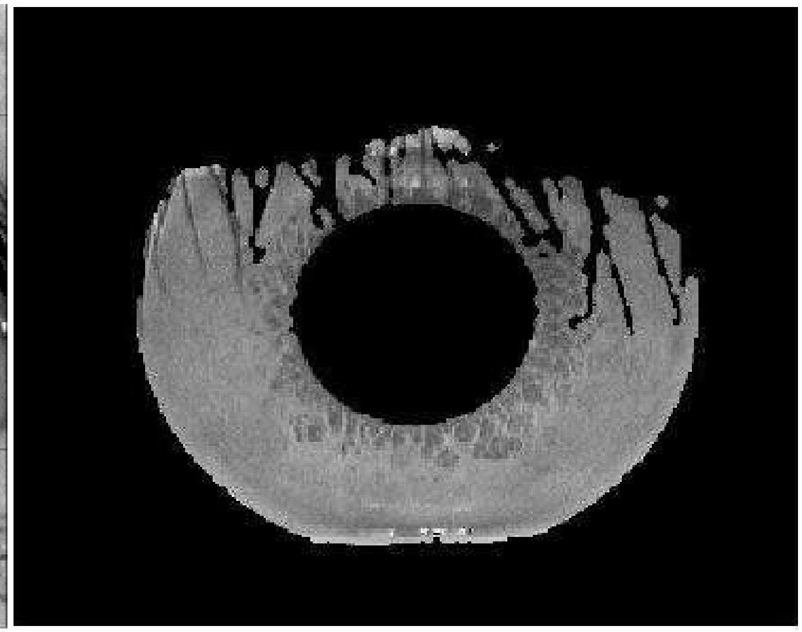
$$v_b i(x,y) = \frac{1}{n^2}\sum_{i=-n}^{n}\sum_{j=-n}^{n} \left(f(x+i, y+j) - u_{bi}(x,y)\right)^2$$

- Thresholding
- Connective Criterion

Comparison of segmentation

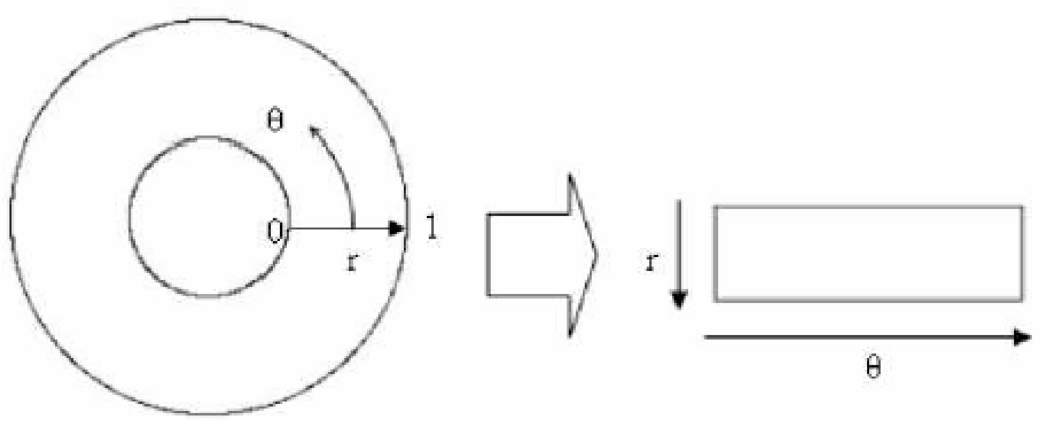
- Regular vs. Enhanced





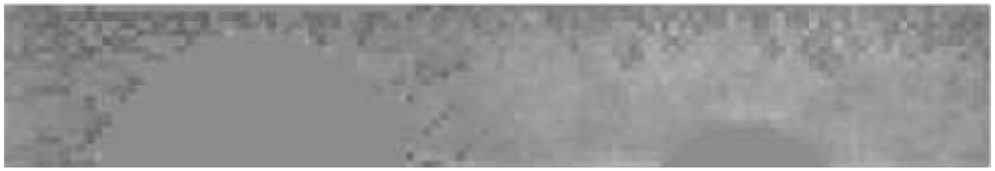
Unwrapping and representation

- Rubber sheet model: map the image from Cartesian coordinates to the normalized polar coordinates

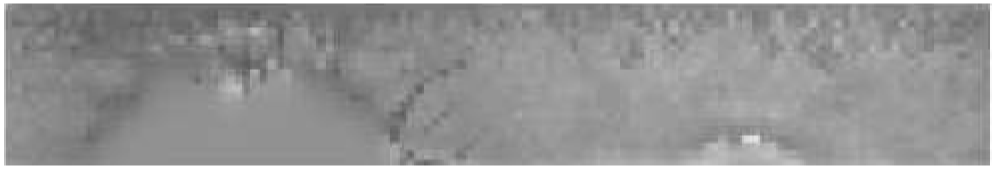


Comparison of unwrapped images

- Regular segmentation

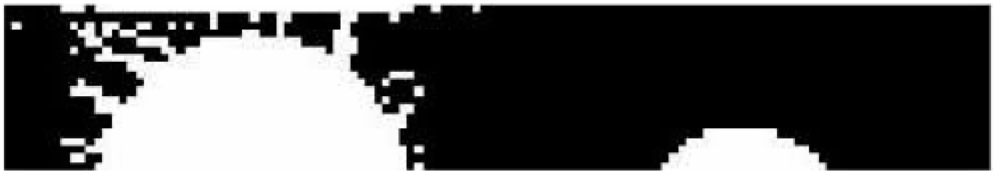


- Enhanced segmentation

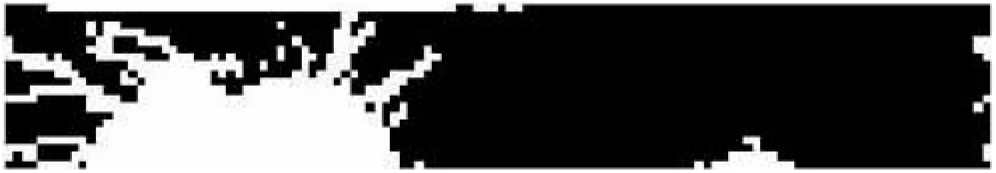


Comparison of masks

- Regular segmentation

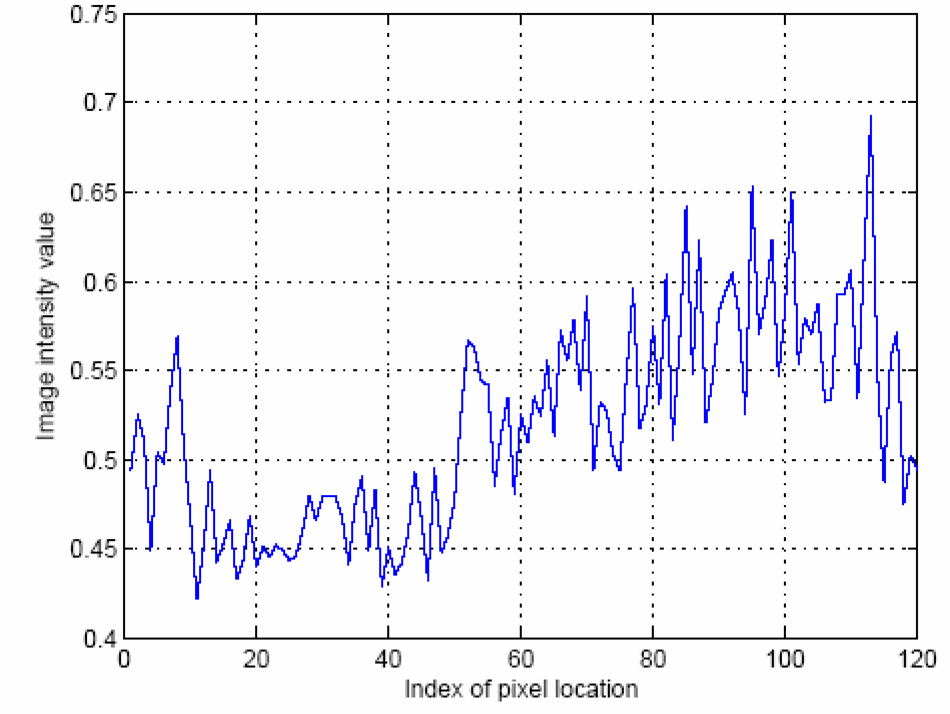


- Enhanced segmentation



Log-Gabor Feature extraction

- Original image intensity vector



- Frequency response of Log-Gabor filter:

$$G(f) = e^{-[log(f/f_0)]^2/2[log(\sigma/f_0)]^2}$$

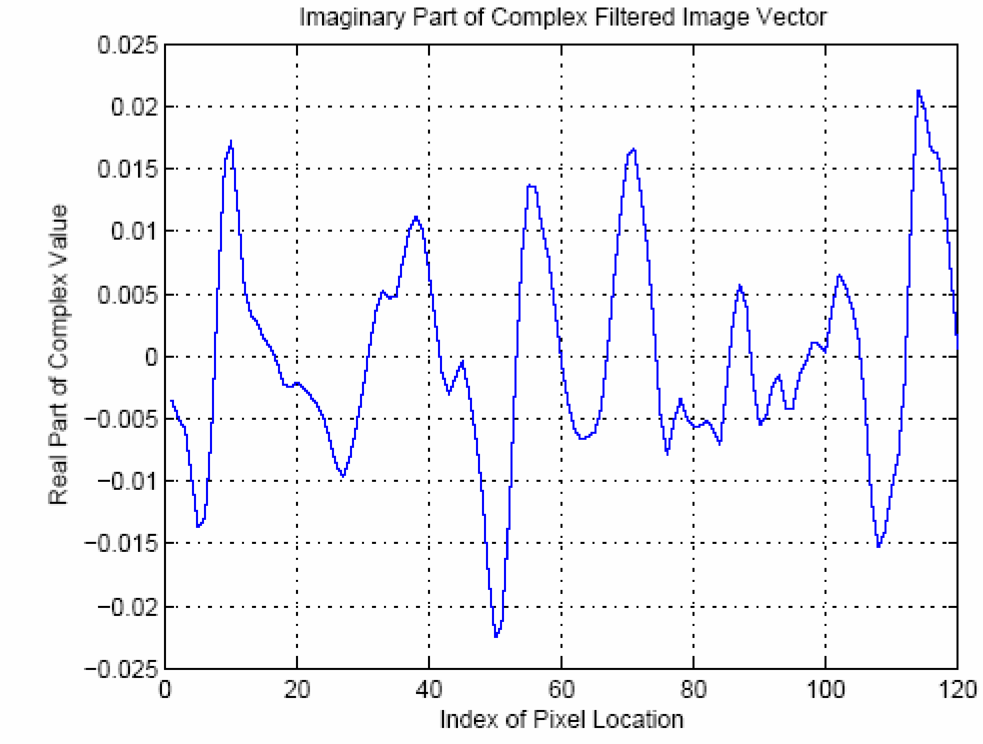
- Unwrapped iris template is convolved with the Log-Gabor filter row-by-row, and generated the complex feature matrix.
- The binary phase representation of each complex value is used as the feature template.

Real-part after convolution

The real part of the image vector after Log-Gabor convolution

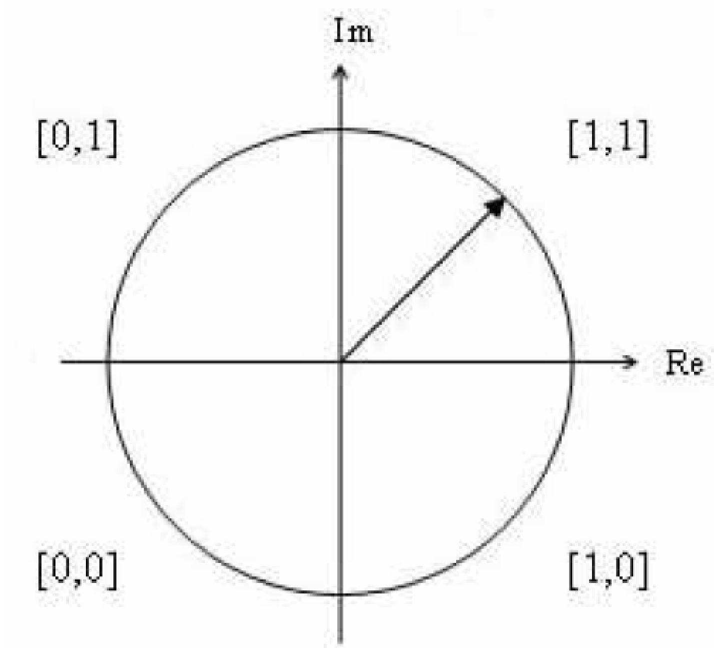
Imaginary-part after convolution

The imaginary part of the image vector after Log-Gabor convolution



Phase encoding template

- Each complex feature point is encoded with the phase binary pairs.



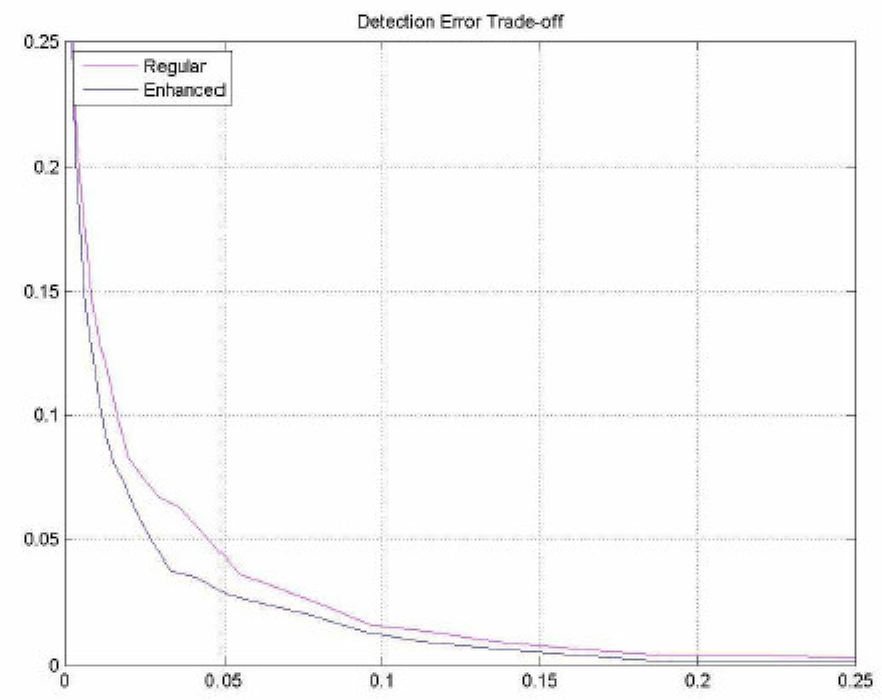
Pattern matching

- Hamming distance as the metric to evaluate the closeness of match

$$HD = \frac{\| (template_A \bigotimes template_B \bigcap mask_A \bigcap mask_B \|}{\| mask_A \bigcap mask_B \|}$$

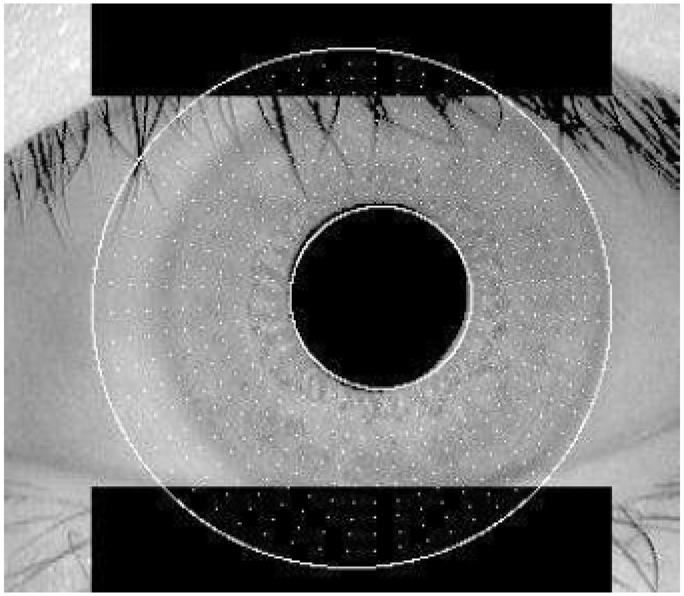
Performance Comparison

- 327 low-quality iris images selected from CASIA database
- FMR-FNMR curve



Erroneous Circular Localization

- Problem with erroneous circular localization of iris and pupil circular boundaries
- 327 iris images with 15 erroneous circular localization



Parameter correction

- Circular parameter representation

$$(x - c_x)^2 + (y - c_y)^2 = r^2$$

- Inline parameter fitting

$$min_{(c_x, c_y, r)} \sum_{i=1}^{N} \left| (x_i - c_x)^2 + (y_i - c_y)^2 - r^2 \right|$$

Recognition algorithm

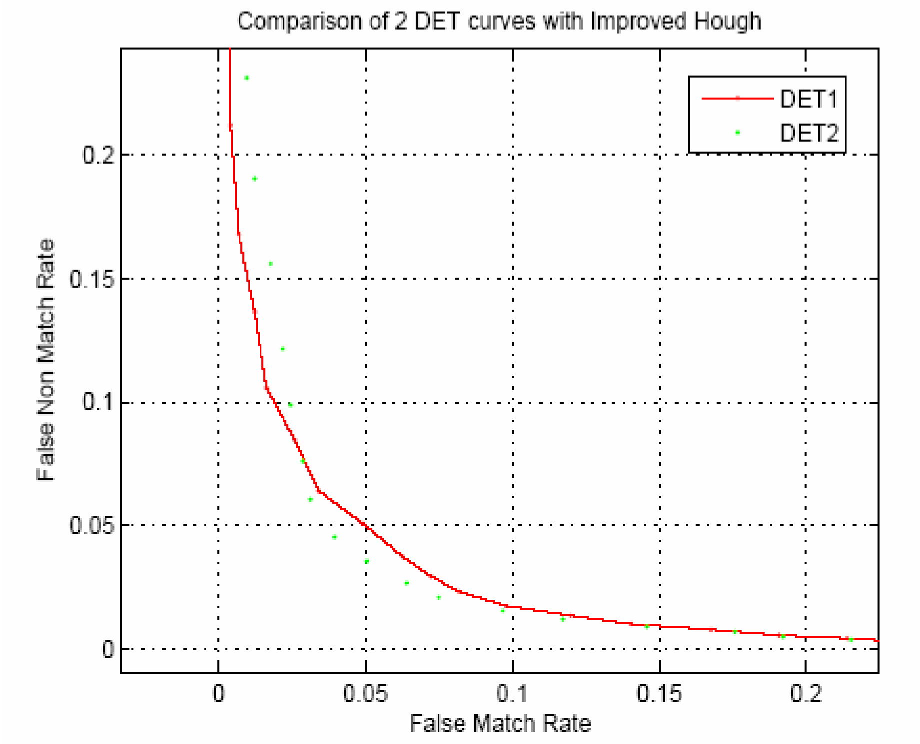
- Daugman Rubber Sheet Model representation
- Log-Gabor feature extraction
- Hamming distance comparison

Performance

- Rank-1 identification rate increases from 96.20% to 96.84%
- Very similar Genuine-Impostor distribution
- Very similar FMR-FNMR curve

Performance

Small improvement in DET curve except in very low FMR range



Covariance Feature with LDA

- Image preprocessing:
  - Segmentation: same method as before
  - Noise elimination: detect the eyelash locations and set these noise pixel intensities to zero
  - Representation: unwrapping according to the Daugman's Rubber Sheet Model

Feature extraction

- Covariance between image rings within iris region along the circumferential direction

$$cov(i,j) = \frac{1}{N-1} \sum ring(i) * ring(j)$$

- Use these covariance values among all image rings as the feature vector

Fisher Discriminating Analysis

- Calculate the within-class covariance matrix:

$$S_W = \sum_k \sum_m (x_m^k - \bar{x}^k)(x_m^k - \bar{x}^k)^T$$

- Singular value decomposition:

$$[U, S, V] = svd(S_W)$$

- Calculate the mapping matrix:

$$M = S^{-1/2} * U'$$

Fisher Discriminant Analysis

- Fisher space mapping:

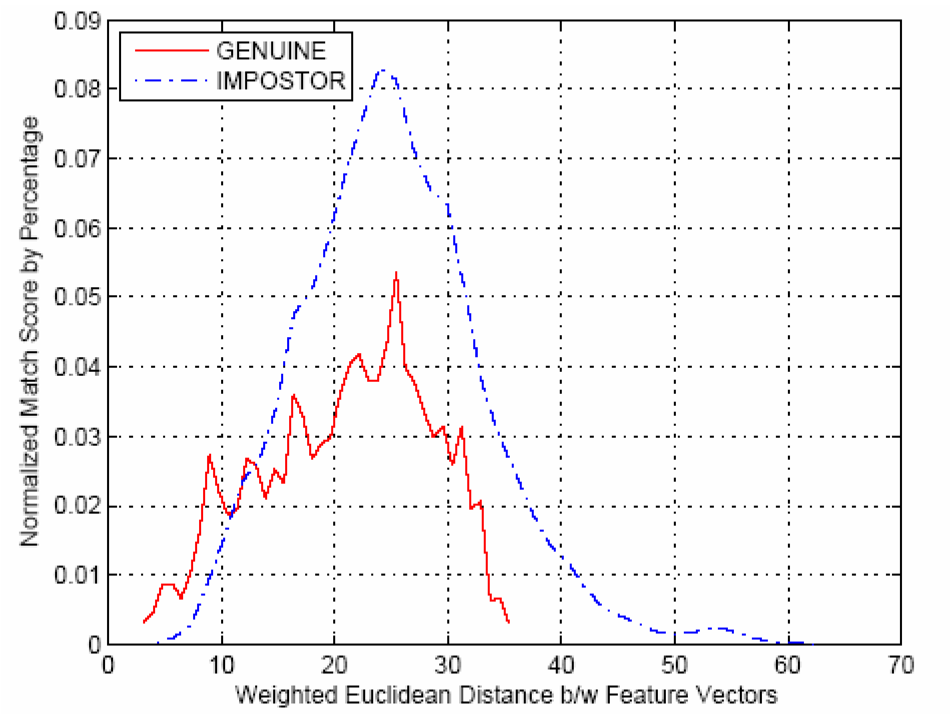
$$F = M * x$$

- Closeness of match

$$D = norm[F_i - F_j]$$

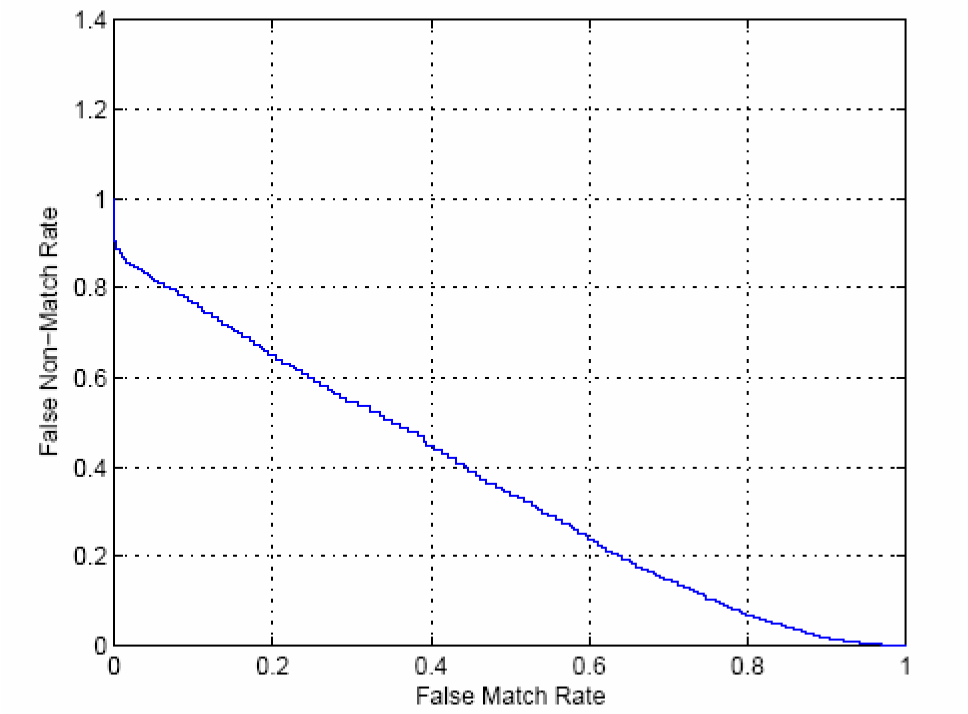
Performance

- Genuine-Impostor distribution



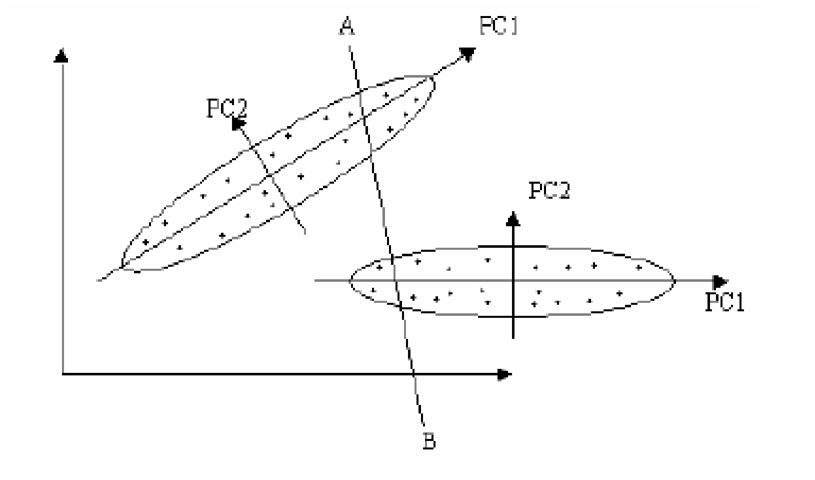
Perforamance

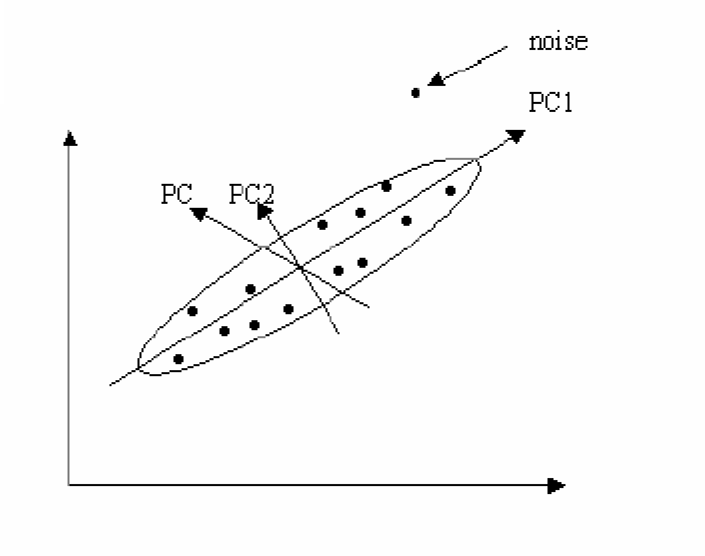
- FMR-FNMR curve



Discussion

- Classification and noise distortion



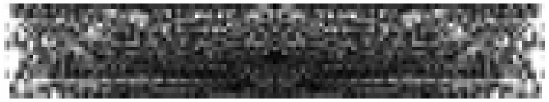


Fourier Magnitudes feature

- Similar preprocessing as before:
  - Segmentation
  - Noise elimination: low-pass filter interpolation
  - Unwrapping according to Rubber Sheet Model
- Feature extraction with the Fourier transform:
  - FFT magnitude vector is circular shift invariant

Original image and feature templates

- Unwrapped image
- 2-D Fourier magnitude matrix feature template
- 1-D Fourier magnitude matrix feature template



Matching Algorithm

- The Euclidean distances are calculated between iris image templates. The smallest Euclidean distance is taken as the closest match.

$$D = norm[F_i - F_j]$$

Performance

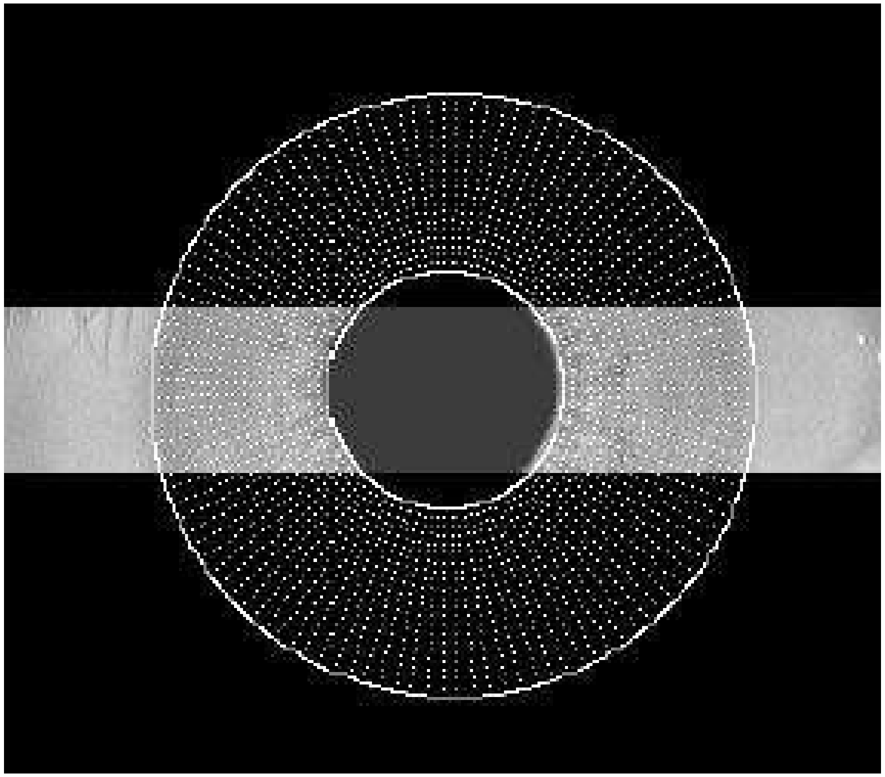
- It achieved a Rank-1 identification rate of 77.68% with 2-D Fourier magnitudes feature templates.
- It achieved a Rank-1 identification rate of 78.28% with 1-D Fourier magnitudes feature templates.

Progressive Segmentation

- Bandwidth:
  - A specified width of iris image area is utilized for feature extraction and pattern comparison.
- Sampling density
  - A collection of feature points with specified resolution is sampled from the segmented iris region, and used for subsequent recognition processing.

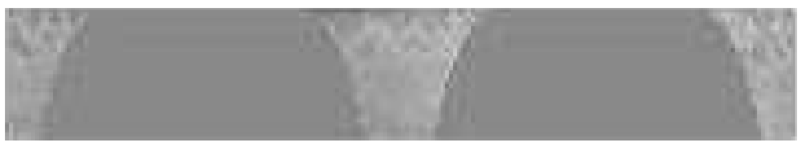
Example

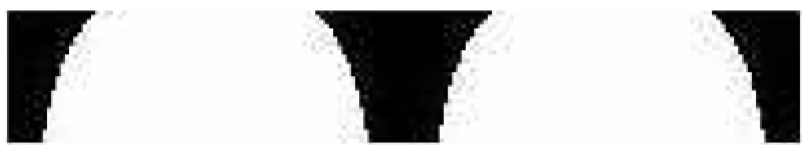
- Bandwidth = 60
- Sampling resolution = [20 120]:
  - 20 image points along radial direction
  - 120 image points along circumferential direction



Representation

- The original segmented image is unwrapped according to Daugman's Rubber Sheet Model: the image template and the mask.



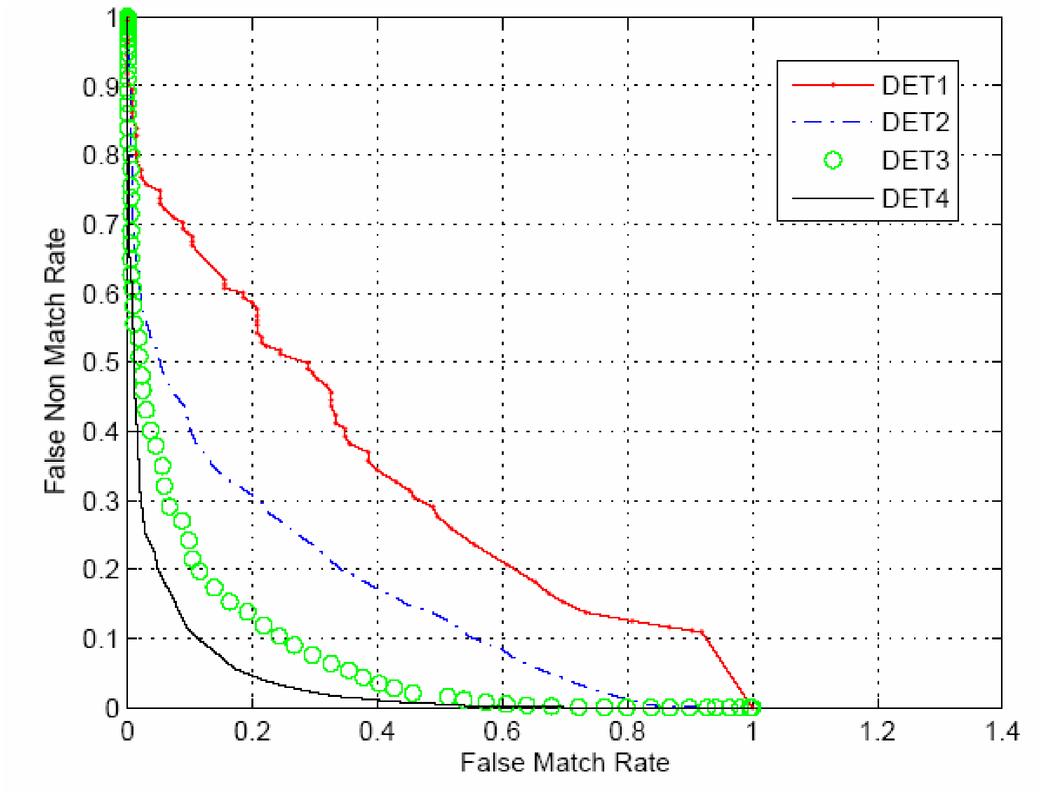


Pattern matching

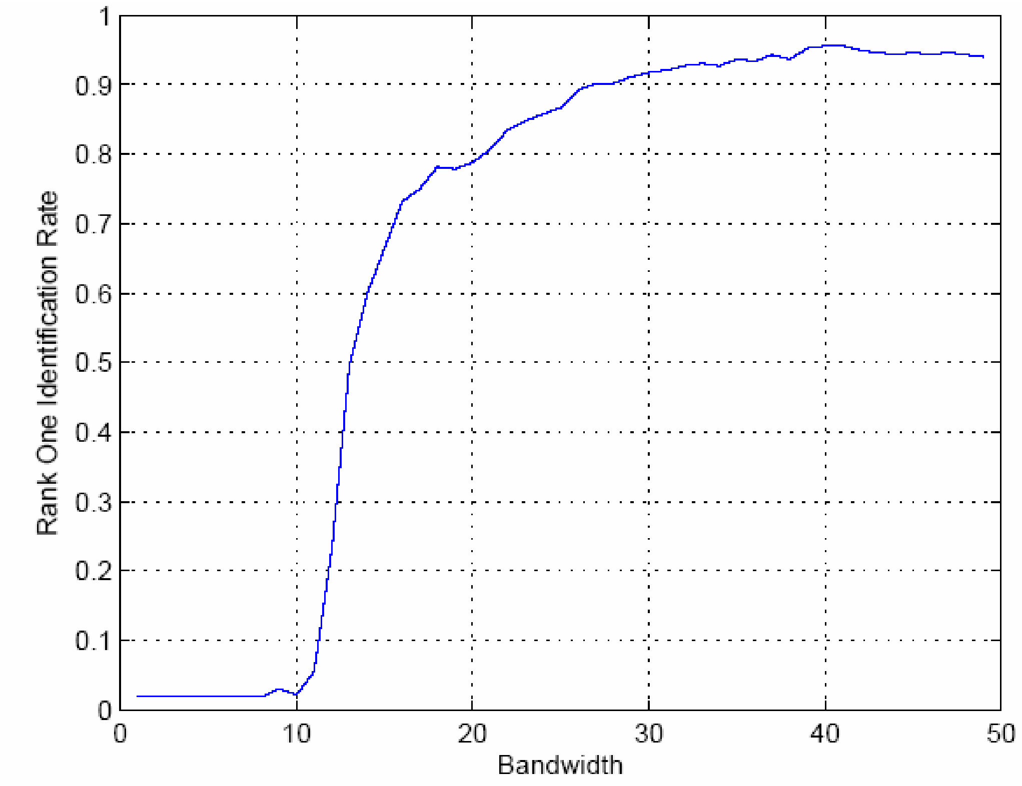
- The unwrapped iris image is convolved with Log-Gabor filter to generate complex feature matrix.
- Binary phase representation is extracted from the complex matrix as the comparison templates.
- Hamming distance is calculated between binary feature template as the decision metric.

Performance with Progressive Bandwidth Segmentation

- DET curve comparison: DET1, DET2, DET3, DET4 correspond to bandwidth of 20, 40, 60 and 80 respectively.

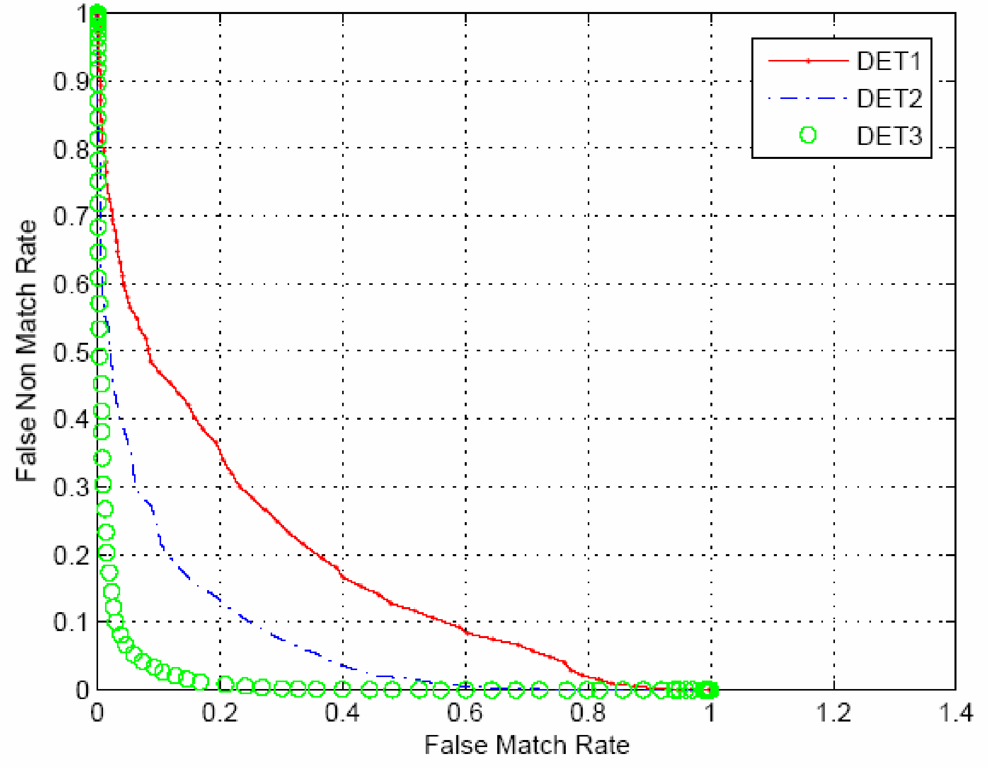


- Identification rate with progressive bandwidth from 2 to 100

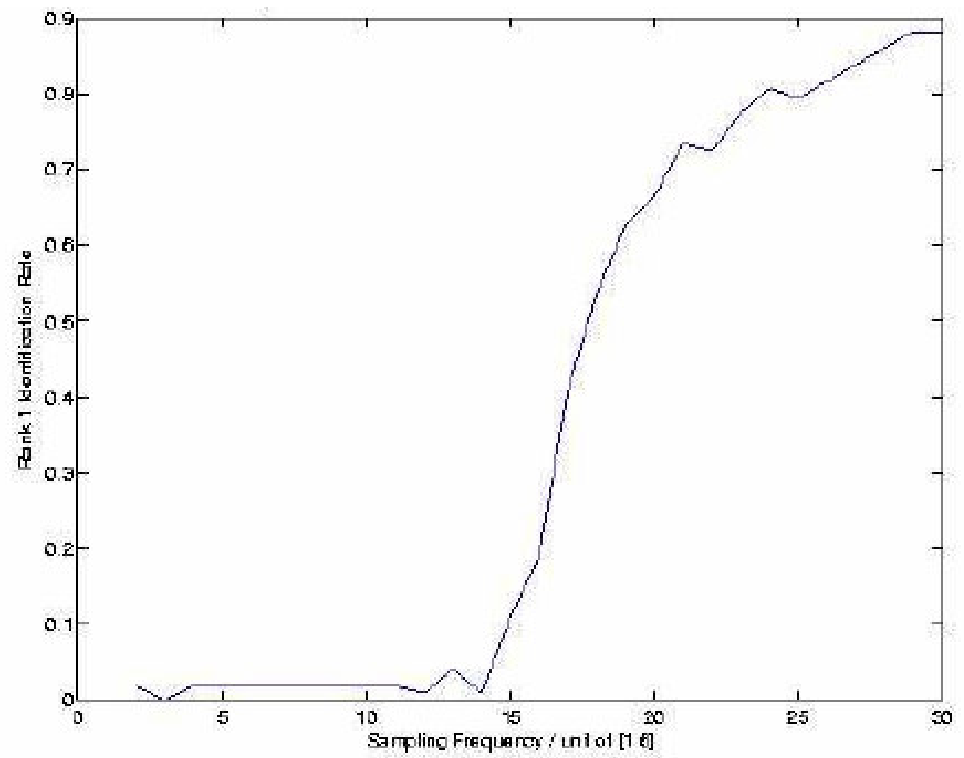


Performance with Progressive Sampling Resolution

- DET1, DET2 and DET3 correspond to sampling resolution of [10 60], [20 120] and [30 180] respectively.



- Identification rate with progressive sampling resolution from [3 18] to [30 180]



Conclusion

- Iris recognition performance could be improved with low quality iris images:
  - Eyelash detection and elimination
  - Improved circular localization
  - Rotational invariant feature extraction
  - Increased valid iris image area and resolution