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

\[ \psi(F) = \log\left(\frac{255 - F}{F}\right) \]

- 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 -1 -1
```

```
  2 -1 -1
-1  2 -1
-1 -1  2
```

```
-1 -1  2
-1  2 -1
  2 -1 -1
```

- Convolution

\[
R_4(x, y) = \sum_{m=-N}^{N} \sum_{n=-N}^{N} I(x - m, y - n) M(m, n)
\]

- Thresholding
- Connective Criterion
Multiple eyelashes detection

- Local statistics

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

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

- 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

![Graph showing Imaginary Part of Complex Filtered Image Vector](image)
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

\[ HD = \frac{\| \left( \text{template}_A \bigotimes \text{template}_B \right) \cap \text{mask}_A \cap \text{mask}_B \|}{\| \text{mask}_A \cap \text{mask}_B \|} \]
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

\[ \text{cov}(i, j) = \frac{1}{N-1} \sum \text{ring}(i) \times \text{ring}(j) \]

- 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:

\[ M = S^{-1/2} \times U' \]
Fisher Discriminant Analysis

- Fisher space mapping:
  \[ F = M \times x \]
- Closeness of match
  \[ D = \text{norm}[F_i - F_j] \]
Performance

- Genuine-Impostor distribution
Performance

- 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.

\[ D = \text{norm}[F_i - F_j] \]
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
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