Iris and Face Recognition System on Mobile Device

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2 Iris and Face Recognition on Mobile Device

3 Conclusion
Introduction


Pier 2.4

HIDE 4

HIDE expansion module jump kit
CrossMatch Mini-Multimodal Jump Kit Fingerprint, Iris (Dual), Face $18,000 (law enforcement/military) [1]

Introduction (Cont.)

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Introduction (Cont.)

- Limitation of uni-modal biometrics
  - Face
    - The changes of illumination, pose, expression, etc
  - Iris
    - Narrow eyes, hand trembling, specular reflection on glasses
Introduction (Cont.)

- **Conventional mobile biometric system**
  - Low processing power
  - Limitation of the number of enrolled templates
  - Fusion on decision level

New multimodal biometric system based on face and iris recognition

Iris and Face Recognition on Mobile Device (1)

Face Recognition

1. Acquiring face image
   - Face and eye detection by Adaboost algorithm
     - The size of detected region > T
       - No
       - Yes
         - Size and illumination normalization (Retinex)
         - Feature extraction by PCA
         - Euclidean distance

Iris Recognition

1. Acquiring iris image
   - Detection of iris and pupil region
     - Liveness detection
       - No
       - Yes
         - Detection of eyelid, eyelash
         - Generating iris code
         - Hamming distance

Score fusion by SVM
Identification

Fusion of Face and Iris recognition
Iris and Face Recognition on Mobile Device (1)

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H/W platform
- Sony VGN-UX17LP UMPC[1-3]
  - Intel core 1.2GHz
  - 512 SDRAM
  - 30GB hard disc

<table>
<thead>
<tr>
<th></th>
<th>Face</th>
<th>Iris</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image size</td>
<td>640×480 pixel</td>
<td>640×480 pixel</td>
</tr>
<tr>
<td>Number of image</td>
<td>487 images (38 Class)</td>
<td>487 images (38 Class)</td>
</tr>
<tr>
<td>Composition</td>
<td>10-22 images per class neutral, smile, angry, surprise</td>
<td>10-22 images per class with /without glasses or contact lens</td>
</tr>
</tbody>
</table>

[4] Song-yi Han, Kang Ryoung Park, “Multi-modal Face and Iris Recognition using Mobile Phones based on a Hierarchical SVM,” JCST in review
Iris and Face Recognition on Mobile Device (1)

Score value by iris recognition

 Authentic Data: 449
 Imposter Data: 16,613

Performance

<table>
<thead>
<tr>
<th>Type</th>
<th>EER(%)</th>
<th>Processing time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Face</td>
<td>10.611%</td>
<td>767 ms</td>
</tr>
<tr>
<td>Iris</td>
<td>0.437%</td>
<td>995 ms</td>
</tr>
<tr>
<td>SVM</td>
<td>0.039%</td>
<td>0 ms</td>
</tr>
</tbody>
</table>
Iris and Face Recognition on Mobile Device (2)

- Feature extraction based on iris tensile property

  Iris recognition with sunlight: contraction and dilation of pupil
  → nonlinear deformation of iris patterns (FRR)
Iris and Face Recognition on Mobile Device (2)
Experimental results

(1) CASIA ver.3 Lamp (The numbers of subjects and classes were 411 and 819.
Each class included 19 ~ 20 iris images for a total of 16,213)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>0.932</td>
<td>0.714</td>
<td>0.621</td>
</tr>
</tbody>
</table>

(2) Image by lap-made camera

Iris quality evaluation on mobile system


Restoration of motion blurred iris image caused by hand trembling

\[ H(x, y) = \begin{cases} \frac{1}{K}, & \text{if } 0 \leq |y| \leq K \cos \left( \frac{\pi}{2} \right) \text{ and } 0 \leq |x| \leq K \sin \left( \frac{\pi}{2} \right) \\ 0, & \text{otherwise} \end{cases} \]

\[ \hat{G}(u, v) = \left( \frac{H^*(u, v)}{|H(u, v)|^2 + \frac{\beta}{y + |H(u, v)|^2}} \right) G(u, v) \]
Restoration of motion + optical blurred iris image caused by hand trembling

\[ \hat{F}(\alpha, \gamma) = \frac{F_{new}(\alpha, \gamma)}{\sqrt{H_{new}(\alpha, \gamma)^2 + \sigma F(\alpha, \gamma)^2 + \frac{\beta}{\gamma + H_{new}(\alpha, \gamma)^2}}} \]
Iris and Face Recognition on Mobile Device (5)

NICE (Noisy Iris Challenge Evaluation – Part I) (http://nice1.di.ubi.pt)
- Contest of iris region segmentation (Ghost, Off-angle, Blur, Misalignment, Rotation, dark, occluded by eyelash, eyelid, hair, glasses, contact lens and SR, small size, closed eye etc)
Iris and Face Recognition on Mobile Device (6)

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Iris and Face Recognition on Mobile Device (6)

Input image

Pupil and iris detection (CED)

Eyelid/eyelash detection

Detection of closed eye (falsely detected iris) by SR

AdaBoost Eye Detector

Color segmentation of iris region

Iris detection

Ground truth

(a) Local iris region of RGB channels
(b) RGB channel histogram of local iris region
Iris and Face Recognition on Mobile Device (6)

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![Eye Images](image)

![Graph](image)

<table>
<thead>
<tr>
<th>Type of Distance</th>
<th>E1 error rate (%)</th>
<th>E2 error rate (%)</th>
<th>FP (False Positive %)</th>
<th>FN (False Negative %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mahalanobis</td>
<td>2.5</td>
<td>13.15</td>
<td>1.4</td>
<td>24.9</td>
</tr>
<tr>
<td>Euclidean</td>
<td>2.7</td>
<td>11.6</td>
<td>1.9</td>
<td>21.3</td>
</tr>
<tr>
<td>Cosine</td>
<td>2.9</td>
<td>12.35</td>
<td>2.1</td>
<td>22.6</td>
</tr>
</tbody>
</table>
The 5th rank among 97 teams (http://nice1.dl.ubi.pt/)

<table>
<thead>
<tr>
<th>Ranking</th>
<th>Username</th>
<th>Affiliation</th>
<th>Country</th>
<th>Error</th>
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<tbody>
<tr>
<td>1</td>
<td>CASTIA</td>
<td>National Laboratory of Pattern Recognition, Institute of Automation, Chinese Academy of Sciences</td>
<td>China</td>
<td>0.0131</td>
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<tr>
<td>2</td>
<td>DMCS</td>
<td>Department of Microelectronics and Computer Science, Technical University of Lodz</td>
<td>Poland</td>
<td>0.0162</td>
</tr>
<tr>
<td>3</td>
<td>Palmeida</td>
<td>Department of Computer Science, University of Beira Interior</td>
<td>Portugal</td>
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<tr>
<td>4</td>
<td>PeihuaLi</td>
<td>College of Computer Science and Technology, Heilongjiang University</td>
<td>China</td>
<td>0.0224</td>
</tr>
<tr>
<td>5</td>
<td>Kang Ryoung Park</td>
<td>Dept. of Electronics Engineering, Dongguk University, Biometrics Engineering Research Center</td>
<td>Korea</td>
<td>0.0282</td>
</tr>
<tr>
<td>6</td>
<td>CATE</td>
<td>Department of Electrical and Computer Engineering, Florida International University</td>
<td>USA</td>
<td>0.0297</td>
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<tr>
<td>7</td>
<td>Itbiolab</td>
<td>Biolab, Department of Information Technologies, University of Milan</td>
<td>Italy</td>
<td>0.0301</td>
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<tr>
<td>8</td>
<td>Font</td>
<td>Department of Electronic Engineering, Universidad Politécnica de Madrid</td>
<td>Spain</td>
<td>0.0305</td>
</tr>
</tbody>
</table>

• Eliminating the ghost region in iris area

Iris recognition with sunlight:
- Its gray level is lower than SR (Specular Reflection) and similar or higher than iris pattern
- The performance of iris recognition is degraded
Iris and Face Recognition on Mobile Device (7)

- Eliminating the ghost region (1) – Histogram Equalization & Binarization

(a) Preprocessing

(b) Iris image

(c) Normalization

(d) Histogram Equalization

(e) Binarization

(f) Eliminating Ghost Region
- Eliminating the ghost region (2) – Connectivity of iris pattern
Performance evaluation of low resolution iris image
- Replacement of costly zoom lens or mega pixel camera
- Reducing the image acquisition time of face and iris on mobile device

→ Motivation of super-resolution iris restoration

CASIA ver 3 Interval
(249 people, 396 classes,
2,655 images)

\[
f(x, y) = \begin{cases} 
1 & \text{if } (x - z \cdot x_1)^2 + (y - z \cdot y_1)^2 \geq z \cdot r^2 \\
1 & \text{if } (x - z \cdot x_2)^2 + (y - z \cdot y_2)^2 \leq z \cdot r^2 \\
0 & \text{otherwise}
\end{cases}
\]

\[
f(x, y) = \begin{cases} 
1 & \text{if } (\sin \theta \cdot (x - z \cdot h_1) + \cos \theta \cdot (y - z \cdot k_1))^2 \\
& \geq a \cdot (\cos \theta \cdot (x - z \cdot h_2) - \sin \theta \cdot (y - z \cdot k_2))^2 \\
1 & \text{if } (\sin \theta \cdot (x - z \cdot h_3) + \cos \theta \cdot (y - z \cdot k_3))^2 \\
& \leq a \cdot (\cos \theta \cdot (x - z \cdot h_4) - \sin \theta \cdot (y - z \cdot k_4))^2 \\
0 & \text{otherwise}
\end{cases}
\]
Super-resolution iris image restoration by using parallel MLPs (multiple layer perceptrons)
- Randomized iris patterns are generated by three parallel MLPs and bilinear interpolation

\[ P = (I_1 + I_3) - (I_2 + I_4) \]
\[ V = (I_1 + I_2) - (I_3 + I_4) \]
\[ D = \begin{cases} 
\text{vertical} & \text{if } (V - P) \leq T \\
\text{non-edge} & \text{if } -T \leq (V - P) < T \\
\text{horizontal} & \text{otherwise} 
\end{cases} \]

CASIA ver 3 Interval
(249 people, 396 classes 2,655 images)
12 images from 12 classes are used for training, reduced 2,655 images are used for testing
### Iris and Face Recognition on Mobile Device (9)

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<table>
<thead>
<tr>
<th>Resolution of image</th>
<th>EER (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original image (320×280)</td>
<td>0.573</td>
</tr>
<tr>
<td>Low resolution image (106×93)</td>
<td>3.327</td>
</tr>
<tr>
<td>Low resolution image + Bilinear</td>
<td>0.622</td>
</tr>
<tr>
<td>Low resolution image + MLP + Bilinear</td>
<td>0.610</td>
</tr>
</tbody>
</table>

#### EER at the 6% Low Resolution Images

<table>
<thead>
<tr>
<th>Resolution of image</th>
<th>EER (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original image (320×280)</td>
<td>0.573</td>
</tr>
<tr>
<td>Low resolution image (80×70)</td>
<td>7.422</td>
</tr>
<tr>
<td>Low resolution image + Bilinear</td>
<td>0.809</td>
</tr>
<tr>
<td>Low resolution image + MLP + Bilinear</td>
<td>0.720</td>
</tr>
</tbody>
</table>

Iris and Face Recognition on Mobile Device (10)

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(a) Indoor

(b) Outdoor

Size Normalization (32 x 32)

Capturing Facial Image

Detecting face region based on Adaboost

Detecting eye region based on Adaboost

Preprocessing (Size and Illumination Normalization)

Face Recognition
Illumination Normalization

Retinex filter

\[ L(x, y) = I(x, y) \times R(x, y) \]
\[ \log L(x, y) = \log(I(x, y) \times R(x, y)) \]
\[ \log R(x, y) = \log L(x, y) - \log I(x, y) \]
\[ I(x, y) = L(x, y) \times \text{Gaussian filter} F(x, y) \]
\[ \log R(x, y) = \log L(x, y) - \log(\log L(x, y) \times F(x, y)) \]

L(x,y) : image intensity
I(x,y) : illumination value
R(x,y) : reflectance ratio

Capturing Facial Image
Detecting face region based on Adaboost
Detecting eye region based on Adaboost
Preprocessing (Size and Illumination Normalization)
Face Recognition
Iris and Face Recognition on Mobile Device (10)

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Experimental Results

<table>
<thead>
<tr>
<th>Face Modeling Method</th>
<th>Histogram Equalization</th>
<th>Histogram Stretching</th>
<th>Retinex</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCA</td>
<td>31.763</td>
<td>31.643</td>
<td>16.896</td>
</tr>
<tr>
<td>LNMF</td>
<td>29.601</td>
<td>26.498</td>
<td>21.196</td>
</tr>
<tr>
<td>LBP</td>
<td>27.114</td>
<td>27.440</td>
<td>21.123</td>
</tr>
<tr>
<td>PCA + LBP</td>
<td>29.082</td>
<td>27.548</td>
<td>16.280</td>
</tr>
<tr>
<td>LNMF + LBP</td>
<td>35.842</td>
<td>33.853</td>
<td>23.068</td>
</tr>
</tbody>
</table>

The face images with illumination normalization:
(a) original image (b) with histogram equalization
(c) with histogram stretching (d) with Retinex filter

Gi Pyo Nam, Byung Jun Kang, and Kang Ryoung Park, "Face Recognition Robust to the Variation of Illumination on Mobile Device," Optical Engineering, Submitted
Conclusion

- Face and iris recognition on mobile device
  - Super-resolution iris image restoration
  - Restoration of optical and motion blurred iris image

- Combining face and iris recognition by SVM
  - Recognition accuracy is enhanced by multimodal biometrics

- Face and iris recognition robust to the illumination variation in outdoor
  - Eliminating ghost region in iris area
  - Face recognition robust to the illumination variation in outdoor