Systematic Analysis of Facial Recognition Improvements in Multiple FRGC Challenges

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Viisage Technology
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Outline

- Scanner Characteristics & Illumination Correction
- 3D Face Recognition
- High Resolution Data
- Overview to all Challenges
- Conclusions & Outlook
- References
Scanner Characteristics & Illumination Correction
Image Preprocessing
Color Conversation (Minolta Scanner)

Observations
- R, G, B, and 3D scan not recorded at the same time resulting in motion artifacts (e.g. pose correction)
- G, B rather dark

Corrective Actions
- Modification of standard RGB to grey conversion, i.e. only use of R channel
- Application of illumination correction algorithms
- Mixed dataset experiments (Exp. 5 & 6) must be handled separately
Image Preprocessing - Results

Results

- Exp. 3t: Accuracy on single channels – R>G>B
- Exp. 5: Some overexposure on red channel of controlled dataset, R only is worse than RGB to grey conversion \((2R+7G+1B)/10\)
- Exp. 6: Underexposure in all channels of uncontrolled dataset, R better than RGB to grey conversion \((2R+7G+1B)/10\)

<table>
<thead>
<tr>
<th></th>
<th>(2R+7G+1B)/10</th>
<th>R</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment 3</td>
<td>-</td>
<td>1.2% / 96.7%</td>
<td>2.7% / 92.4%</td>
</tr>
<tr>
<td>Experiment 5</td>
<td>4.2% / 79.3%</td>
<td>4.1% / 76.5%</td>
<td>-</td>
</tr>
<tr>
<td>Experiment 6</td>
<td>5.2% / 76.1%</td>
<td>4.4% / 77.9%</td>
<td>-</td>
</tr>
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</table>

* EER / Verification@FAR 0.1%
Illumination Correction (I)

Regression Over Grey Level Values in Facial Area

- Symmetry assumption, compensates for the slant of the regression plane
- Standardized image to fixed mean value and fixed variance

Gradient Compensation → Normalization → Background Suppression

Best Fit Plane → Fixed Mean → Constant Gray Value around Face

Regression → Fixed Variance
Neighborhood Dependent Approaches

- Cooperation with Prof. Vijayan Asari, Old Dominion University
- Two approaches evaluated and optimized
  - HPSRR [Asari, Seow, 2004]
  - INDANE [Tao, Asari, 2004]

Experimental Setup

- Subset of FRGC Experiment 4
  - Gallery: 466 controlled images
  - Probe: 958 uncontrolled images
  - Training: 400 controlled, 400 uncontrolled images
Evaluation Methods
- Two different recognition engines
- Enhanced images are used as input to recognition engine
- Verification and identification scenario

Results
- Both illumination correction methods improves Viisage’s FR accuracy
  - INDANE better than HPSRR (HPSRR annihilates small features)
  - Improvement higher with VISG1 (VISG2 already contains regression based illumination correction)
3D Facial Recognition
Fusion Strategies for 2D/3D Algorithms

Fusion on algorithmic level
- Landmark finding (2D, 3D)
- Pose estimation (2D, 3D)
- Pose correction (2D, 3D)
- ...

Fusion on score level
- Shape and texture yield independent scores and quality (confidence)
- Fusion of scores

Face detection (video, still)

2D landmark finding on texture image

Pose estimation

Pose estimation

Rendering of texture (shape) in frontal view

2D landmark finding on pose transf. image

Features from texture image

Features from shape image

Features from texture + shape Score fusion

Extension to 3D (precision, ...)

Extension to 3D (precision, > 30 deg.)

Extension to 3D (shape, precision, ...)

Extension to 3D (precision, ...)

Face detection (video, still)
Viisage’s 3D Approach (DICAR)

**Foundation – HGM**
- Graph is automatically located to landmarks
- Optimized features are extracted at the landmark positions -> facial template
- Correlation in feature space determines the similarity between faces

**Extension to 3D**
- Extension from texture to depth images
- Additional feature extraction on surface data
- Fusion of texture and shape results on score level
Results of Score Fusion

- Texture strongly outperforms shape, even in spite of unbalanced illumination
- Score level fusion yields the best results
Fusion of Algorithms and Scores

- Pose correction based on texture and shape
- 2D landmark finding on pose transf. image
- Features from texture image
- Features from shape image
- Score level fusion

Pose correction yields further improvement in both modalities and after fusion
3D Results on Actual Engine

Results of 2005 are confirmed

- 2D HGM engine only performs at level of 97–98% correct verification rate @ FAR of 0.1%
- Pose correction using 3D shape improves verification rate by approx. 18% in comparison to 2D engine
- Combined pose correction, HGM on shape and score fusion of shape and texture improves verification rate by 37-44% in comparison to 2D engine
- Absolute differences are less than 1% in verification rate
High Resolution Data
High Resolution Data

Motivation
- Analysis of FRGC results (2005)

Solution
- Correlation based method to exploit additional information in high resolution images
- Selection of appropriate areas, where facial micro features are invariant to pose, illumination and expression
- Fully integrated into Viisage’s core FR engine
  - Landmark/region finding
  - Score fusion HGM/Facial Micro Features

![Graph showing verification rate @ FAR=0.1% for ROCIII, non-normalized.](image)

Best FRGC result (Mar 05) vs VISG FRGC results (Mar 05)
Facial Micro Features (FMF)

Results

- Successfully tested on multiple data sets (e.g., FRGC, FERET)
- Significant improvement of accuracy on high resolution images (FRGC experiment #1)
- Unchanged accuracy on insufficient images
- Low matching speed for large scale tests -> hierarchical matching implemented
- Small additional template size (~3kB)
Overview to all Challenges
Evolution of FR Performance (FRGC data)

Verification Rate @ FAR=0.1%

ROCIII, non-normalized

<table>
<thead>
<tr>
<th>Exp1</th>
<th>Exp2</th>
<th>Exp3s</th>
<th>Exp3t</th>
<th>Exp3 (s+t)</th>
<th>Exp4</th>
<th>Exp5</th>
<th>Exp6</th>
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</thead>
<tbody>
<tr>
<td>Best FRGC result (Jan 05)</td>
<td>98,92</td>
<td>100</td>
<td>86,55</td>
<td>96,22</td>
<td>97,28</td>
<td>76</td>
<td>73,9</td>
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<tr>
<td>VISG FRGC results (Jan 05)</td>
<td>97,64</td>
<td>99,96</td>
<td>---</td>
<td>96,22</td>
<td>97,28</td>
<td>60,65</td>
<td>73,90</td>
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<tr>
<td>VISG FRGC results (Apr 05)</td>
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<td>96,88</td>
<td>97,28</td>
<td>68,10</td>
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<tr>
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<td>98,78</td>
<td>100,00</td>
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<td>98,11</td>
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<td>71,75</td>
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<tr>
<td>VISG FRGC results (Mar 06)</td>
<td>98,98</td>
<td>99,91</td>
<td>98,06</td>
<td>98,21</td>
<td>68,12</td>
<td>80,18</td>
<td>84,06</td>
</tr>
</tbody>
</table>
3D vs. Micro Features on Exp. 3

Verification Rate @ FAR=0.1%

- HGM Standard
- HGM & Pose Correction (3D)
- HGM & Pose Correction and 3D Shape
- HGM & FMF
- HGM & Pose Correction & FMF
- HGM & Pose Corr., 3D Shape & FMF

1-1 (non normalized) 1-1 (z-normalized)
→ Conclusions & Outlook
Conclusions and Outlook

Summary
✓ Illumination correction greatly improves recognition on uncontrolled images
✓ High resolution works well for cooperative scenarios
✓ High resolution adds more than 3D
✓ We used a general purpose FR system in contrast to prior submissions

Outlook
✓ FRGC provided a cornerstone to improve FR systematically
✓ FRGC focused on specific aspects (high resolution, 3D)
✓ There are scenarios like low resolution, images with pose, and video processing that have been left untouched
✓ FRGC II may focus on those
✓ Thanks to Jonathon Philips and TSWG
✓ Thanks to all people, that contributed to the collection of datasets either with their faces or their heads.
THANK YOU!

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