Preliminary Covariate Analysis
Results for a Fusion of Three FRVT 2006 Algorithms.

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Overview

• **Scope of the Study**
  – FRVT 2006 Uncontrolled to Controlled Imagery.
  – Fusion of three top algorithms.

• **Approach**
  – Generalized Linear Mixed Effect (GLMM) Model.

• **Covariates**
  – Properties of subjects, environment and imagery.

• **Findings**
  – Scientifically significant effects and interactions.
Scope of the Study

• Uncontrolled Imagery matched to Controlled.

• 345 subjects and 110,514 match scores.
Scope of the Study - Covariates

• Performance Variable
  – Verification Outcome, Success of Failure.

• False Accept Rate - FAR

• Properties of Environment
  – Mugshot lighting, indoor uncontrolled, outdoor.

• Attributes of People
  – Gender, Race, Age.

• Measurable Properties of Imagery
  – Distance between Eyes.
  – Face Region In Focus Measure (FRIFM).
    • An edge-density measure by Eric Krotkov*

* “Active Computer Vision by Cooperative Focus and Stereo” by Eric Krotkov.
From Covariate to Quality Metric

• An actionable covariate
  – some degree of control
## Factors Affecting Face Image Quality

<table>
<thead>
<tr>
<th>Character</th>
<th>Behavior</th>
<th>Imaging</th>
<th>Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>RICHNESS OF IDENTIFYING CHARACTERISTIC – BIOLOGICAL CHARACTERS</td>
<td>SPOOFING</td>
<td>ACQUISITION PROCESS AND CAPTURE DEVICE PROPERTIES</td>
<td>AMBIENT CONDITION</td>
</tr>
<tr>
<td>FACE</td>
<td></td>
<td></td>
<td>1. dynamic characteristics of the background like moving objects</td>
</tr>
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<td>1. image enhancement and data reduction process</td>
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<td>3. ethnic group</td>
<td>3. hair across the eye</td>
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<td>• uneven lighting on the face area</td>
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<td>4. impairment</td>
<td>4. head pose</td>
<td>4. static properties of the background (e.g. wallpaper)</td>
<td>• extreme strong or weak illumination</td>
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<td>5. Heavy facial wears, such as thick or dark glasses</td>
<td>5. makeup</td>
<td>5. camera characteristics • sensor resolution</td>
<td>3. subject posing, e.g.:</td>
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<tr>
<td></td>
<td>6. subject posing (frontal / non-frontal to camera)</td>
<td>6. scene characteristics • geometric distortion</td>
<td>• too far (face too small), or too near (face too big)</td>
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<td></td>
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<td>• partial occlusion of the face</td>
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### Face Image Characteristics

- 1. anatomical characteristic (e.g. head dimensions, eye position)
- 2. injuries and scars
- 3. ethnic group
- 4. impairment
- 5. Heavy facial wears, such as thick or dark glasses

### Face Image Behaviors

- 1. closed eyes
- 2. (exaggerated) expression
- 3. hair across the eye
- 4. head pose
- 5. makeup
- 6. subject posing (frontal / non-frontal to camera)

### Face Image Imaging

- 1. image enhancement and data reduction process
- 2. physical properties (e.g. resolution and contrast)
- 3. optical distortions
- 4. static properties of the background (e.g. wallpaper)
- 5. camera characteristics • sensor resolution
- 6. scene characteristics • geometric distortion

### Face Image Environment

- 1. dynamic characteristics of the background like moving objects
- 2. variation in lighting and relate potential defects as
  - deviation from the symmetric lighting
  - uneven lighting on the face area
  - extreme strong or weak illumination
- 3. subject posing, e.g.: • too far (face too small), or too near (face too big) • out of focus (low sharpness) • partial occlusion of the face
Generalized Linear Mixed Model (GLMM)

Analysis is: *Mixed Effects Logistic Regression with Repeated Measures on People.*

- Let $A$ and $B$ be 2 covariates that might influence algorithm performance. For example, $A=$ gender (categorical) and $B=$ Query-Eye-Distance (continuous).
  - Let $a$ index levels of $A$.
- Let $j$ index the FAR setting, $\alpha_j$.
- $Y_{pabj}$ is
  - 1 if Person $p$ is verified correctly, 0 otherwise.
- $Y_{pabj}$ depends on:
  - person $p$, covariates $A$ and $B$, and
  - false alarm rate $\alpha_j$. 
GLMM Model Continued …

\[ Y_{pabj} \text{ is Bernoulli R.V. with success probability } p_{pabj} \]

\[
\log \left( \frac{p_{pabj}}{1 - p_{pabj}} \right) = \mu + \gamma_a + \gamma_b B + \gamma_j + \gamma_{aj} + \pi_p
\]

- \( \mu \): grand mean
- \( \gamma_a \): effect of setting \( a \) of factor \( A \)
- \( \gamma_b \): effect of covariate \( B \)
- \( \gamma_j \): effect of \( j \)
- \( \gamma_{aj} \): interaction effect between \( A \) and FAR
- \( \pi_p \): subject id. random effect (next page)
Subject Variation

The Mixed in Generalized Linear Mixed effect Model.

$$\begin{bmatrix} \pi_1, \ldots, \pi_n \end{bmatrix}^T \sim \text{Multivariate Normal where}$$

$$E(\pi_p) = 0, \quad \text{Var} \quad \pi_p = \sigma^2_\pi,$$

$$\text{Cor}(y_{pabj}, y_{p'a'b'j'}) = \begin{cases} \phi & \text{if } p = p' \\ 0 & \text{if } p \neq p' \end{cases}$$

This means:

The outcomes, i.e. verification success/failure, are uncorrelated when testing different people but correlated when testing the same person under different configurations.
Finding 1: False Accept Rate

dash = Outdoors
solid = Indoors
Finding 2: Gender

![Graph showing gender probability]

- Solid line = Indoors
- Dash line = Outdoors

Y-axis: Probability of Verification
X-axis: Gender (M to F)
Finding 3: Race

Probability of Verification

dash = Outdoors
solid = Indoors

Race

Asian (30k)  Hispanic (3k)  Unknown (5k)  White (74k)
Finding 4: Glasses

- dash = Outdoors
- solid = Indoors

Probability of Verification

Query Glasses
(Target Never Wore Glasses)
Face Region In Focus Measure

FRIFM: Sum of Sobel edge magnitude inside an ellipse bounding the face.
Face Region In Focus Measure

Low FRIFM examples

High FRIFM examples
Finding 5: Distance Between Eyes, Query Image

Query Location

Outdoor

 Indoor

Small

Medium

Large

Query FRIFM

Target FRIFM

Probability of Verification
Finding 5: Distance Between Eyes, Query Image

Size of query image (distance between eyes)
Finding 5: Distance Between Eyes, Query Image

- Small
- Medium
- Large

Query environment

Query Location

Indoor

Outdoor

Query FRIFM

Target FRIFM

Probability of Verification

0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
Finding 5: Distance Between Eyes, Query Image

Boundary of observed data

Probability of Verification
**Finding 5:** Distance Between Eyes, Query Image

**Indoor**

Small

Medium

Large P

V

Range

~0.90 – ~0.10

**Outdoor**

Small

Medium

Large
Finding 5: Distance Between Eyes, Query Image

Low FRIFM good; even for one image
FRIFM Conclusion

• Large of performance.
  – Indoors [>0.95, ~0.70]
  – Outdoors [~0.90, ~0.10].

• Interaction between covariates
  – Environments (indoors, outdoors)
  – Query image size
  – Target and query FRIFM

• Low FRIFM good
  – Effect if control for only one image

• Outdoors: query size very important
Conclusion

• Quality is NOT in the eyes of the beholder
• It is in the performance numbers

• Model quantifies performance change.
  – Turn the knob.
  – Read off the change in performance.
  – Interaction between covariates

• Tells us where to put our efforts
  – Indoors it is FRIFM.
  – Outdoors it is Query Image Size.

• These models are used in other fields.
  – e.g., Biomedical.

• Biometrics should use these models.
Thank You