Best Practices for Taking Face Photographs and Face Image Quality Metrics

*NIST Biometric Quality Workshop*

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Motivation and Outline

- Motivation for face image quality measurement:
  - U.S. Department of State using automated face recognition for Nonimmigrant, Immigrant, and Diversity Visa application processing
  - Ensure accurate automated and manual face recognition

- Through ISO/IEC JTC1 SC37, proposed adding a best practices Annex to ISO 19794-5 (Information Technology — Biometric Interchange Formats — Part 5: Face Image Data)

- Nature of problem - how should we measure face image quality?
  - Using test patterns
  - Using face images and face image quality metrics
Some Examples of Problems

- Improper color
- Too dark
- Contrast too high

- Over-exposed
- Shadows on face
- Shadow on background
Amendment to Add Best Practices
Annex to ISO 19794-5

AMENDMENT 1, Conditions for Taking Photographs for Face Image Data

Editor: Tetsuo (Ted) Tomonaga of Japan
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Circulated to ISO/IEC JTC1 SC 37 National Bodies for PDAM ballot, with due date of 5-28-2006

- Provides explicit guidance for the design of photographic studios and photo booths
- Supplements information provided in the standard and existing Annex A
- Provides guidance on printing quality and on scanning printed face photographs
Single Lamp Arrangement for a Photo Studio

Side view

- Lamp reflector
- Light
- Side reflector panel
- Camera
- Tripod
- Grey background
- 1.2 - 2.5m
- 35°

Top view

- Lamp reflector
- Light
- Camera
- Plane reflector
- Side reflector panel
- Grey background
- Less than 45°
Lighting and Camera Arrangement for a Photo Booth

**Front view**
- Room light
- Lamp reflectors
- Face positioning frame
- Height adjustable stool
- Background light behind subject

**Side view**
- White inner walls
- Lamp reflector
- Lights
- Camera
- Face positioning frame
- Light
- Revolving stool
- About 35º
- 0.7 – 1m

**Top view**
- Light
- Camera
- Light
- Less than 45º
- Lamp reflector
- Background light
- Grey background
- White inner walls
User Interface: Head Positioning Frame

Confirming position frame example 1: Outer indicator lines

Confirming position frame example 2: Inner indicator lines

Confirming position frame example 3: Inner indicator frame

Centre line

Eye position line

Mirror or video image

Centre line

Eye position line

Mirror or video image

Frame for face size and position

Height adjustable stool
Evenness of Illumination

<table>
<thead>
<tr>
<th>Two lights and a background light</th>
<th>Single light and a side reflector panel</th>
<th>Single light (without a side reflector panel) [NR]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left-Right $\Delta EV=0.2$</td>
<td>Left-Right $\Delta EV=1.5$</td>
<td></td>
</tr>
</tbody>
</table>

Exposure Value: $EV = \log_2 \left( \frac{F^2}{T} \right) = 2\log_2(F) - \log_2(T)$

NR: Not recommended
Effect of Using On-Camera Flash

Note glare on glasses & specular reflections from face, deep shadow on background–blending with dark hair

NR: Not recommended
Example of a Photo Booth

Curtain closure sensor

Flash lamps

Head alignment guide mirror with camera behind the mirror

Touch panel display

White reflecting surfaces for flash lamps above mirror
Example of a Photo Booth

- Neutral grey background
- Head positioning guide
- Shielded flash lamp behind subject
- Height-adjustable stool
- External mirror

Innovative Technology in the Public Interest™
Image Quality Measurements

- Use test targets to calibrate camera (or scanner) and measure its characteristics
  - See http://www.i3a.org/downloads_iso_tools.html
  - Opto-electronic conversion function (OECF) – ISO 14524
  - Spatial frequency response (SFR) – ISO 12233 or ISO 16067-1
  - Noise measurements - ISO 15739
  - Color profile – See www.color.org
- Measure compliance of face images with specifications in ISO 19794-5
Color CCD Using a Typical Bayer* Pattern

CCD color imaging array
½ of the elements are green
¼ are red
¼ are blue

RGB values assigned by interpolation

Overlay also filters out infrared, realigns the light, and provides a low-pass, anti-aliasing filter

* Bryce E. Bayer, Kodak researcher, awarded U.S. Patent #3,971,065, July 20, 1976
Test Chart for Spatial Resolution Measurement: ISO 12233

- Contains many visual indicators of spatial resolution
- Slanted edge targets provide:
  - Oversampling of the edges – edge position resolved to better than a single pixel
  - High-resolution measurement of the edge-spread function (ESF)
  - Noise reduction of the Line Spread Function (LSF) or differentiated ESF
  - Modulation Transfer Function (MTF) through the Fourier transform of the LSF
Slanted Knife Edge (Rotated Square) Target and MTF Measurement Software

ISO 16067-1, Photography - Electronic scanners for photographic images – Spatial resolution measurements – Part 1: Scanners for reflective media

“… specifies methods for measuring and reporting the spatial resolution of electronic scanners for continuous tone photographic prints. … applies to both monochrome and colour print scanners.”
Measured Tonal Response Function (OECF) for a Moderate Quality Digital Still Camera

For details of sRGB, see [http://www.w3.org/Graphics/Color/sRGB](http://www.w3.org/Graphics/Color/sRGB)

\[ y = 214.63x^{0.45} \]

\[ R^2 = 0.99 \]

Exponent for sRGB
\[ \frac{1}{2.2} = 0.45 \]
Modulation Transfer Functions for a Moderate Quality Digital Still Camera

Horizontal MTF
Using Left Vertical Edge

Evidence of sharpening

Vertical MTF
Using Lower Horizontal Edge

MTF Nyquist
Quality Comparison of Direct Digital and Scanned Printed Photo

- Direct digital capture using moderate quality camera with optical zoom
- Same image printed with an inkjet printer using correct passport reduction ratio on glossy photo paper, highest quality setting
- Scanned at 2400 pixels/inch
Depth of Field Calculation

Since \( s \gg f \) and \( f^2 \gg cF \)

\[
D_{DoF} \approx \frac{2cs^2F}{f^2}
\]

Example for a digital SLR:

\( f = 70 \text{mm}, \ s = 1.5 \text{m}, \)

\( F = 8, \ c = 0.016 \text{mm} \)

\( D_{DoF} \approx 12 \text{cm} \)

\( D_{front} \) = the front focal distance, the distance from the object plane to the plane closest to the lens that is still in acceptable focus,

\( D_{rear} \) = the rear focal distance, the distance from the object plane to the plane farthest from the lens that is still in acceptable focus,

\( c \) = the diameter of the circle of confusion,

\( s \) = the object distance, the distance from the lens to the object plane, and

\( F = f/a \) is the F-stop, the lens focal length \( f \) divided by the effective lens aperture \( a \).
Gamuts for *sRGB* and a Scanner

- **High Quality Scanner**
- **sRGB**
- **Macbeth ColorChecker**
- **IT8.7/2**
- **Little CMS**
  - [http://littlecms.com/](http://littlecms.com/)
  - “Liberal open source license”
Desired Face Image Quality Metrics

- **Dynamic Range in Face** – intensity density in the facial region should be at least 7 bits of intensity variation (at least 128 unique values) in face after conversion to grayscale (ISO 19794-5 7.4.2)

- **Eyes Closed/Obstructed** – measured as a percentage, value should reflect degree of obstruction of eyes due to eyeglass rims, tint, or glare, bangs, eye patches, head clothing, or eyes closed (e.g., 100% obstructed if both eyes are closed; 50% obstructed if one eye is obstructed) (7.2.3, 7.2.11)

- **Color Balance** – must reflect natural colors with respect to expected skin tones. This value can be affected by inappropriate white balancing or red-eye (7.3.4)

- **Lighting Uniformity on Face** – measured as a percentage, value should measure symmetry as affected by shadows or hot spots on the face (7.2.7-7.2.10)

- **Background Uniformity** – measured as a percentage, value should measure symmetry and consistency as affected by shadows on the background, textured backdrops, or extraneous objects in the background. (A.2.4.3)

- **Head Size** – Head width to image width ratio should be between 5:7 and 1:2 (8.3.4, 8.3.5, A.3.2.2)

- **Centering** – horizontal and vertical position of face (8.3.2, 8.3.3)

- **Distance Between Eyes** – measured in pixels, should be at least 90 pixels between eyes (8.4.1) and preferably 120 pixels (A.3.1.1)

- **Focus** – measures sharpness and resolution of the facial area. Depth of focus must maintain at least 2 mm per-pixel-resolution and preferably 1 mm per-pixel throughout the face. Image should not be overly sharpened. (7.3.3, A.2.5)

- **Rotation (yaw)** – value should measure deviation from frontal in degrees, compliance requirement is < ± 5° (7.2.2)

- **Tilt (roll)** – value should measure deviation from frontal in degrees, compliance requirement is < ± 5° (7.2.2)

- **Confidence in Face** – measures the confidence of the eye finding and the confidence that the object is a face

- **Brightness Exposure/Contrast** – low score if too dark or too bright, exposure measured in RGB values—gradations in skin texture should be visible, no saturation on the face (7.3.2)
Desired Face Image Quality Metrics

- Would like well-distributed, thresholdable histograms on representative images

- Metrics should measure compliance with ISO 19794-5

- Desire good correlation of metrics with human perception

- At least four face image quality assessment products are commercially available
Results for Animetrics’ Pose Correction Product

- Automatic, batch processing
- Estimates and corrects pitch, roll, yaw (up to 40°)
- User can input eye positions
- User may adjust minimum pose angle for corrections
Cumulative Match Characteristic for Uncorrected and Corrected Pose Angles

Corrected/Uncorrected Frontal Mate

Identification Rate

Yaw = ± 15° Corrected

Yaw = ± 15°

Yaw = ± 25° Corrected

Yaw = ± 25°
Receiver Operating Characteristic for Uncorrected and Corrected Pose Angles

Corrected/Uncorrected Frontal Mate

- Yaw = ± 15° Corrected
- Yaw = ± 15°
- Yaw = ± 25° Corrected
- Yaw = ± 25°