Face Authentication Device Testing

Ethan Chang
Software Engineer
Partner and Customer Engagement
Agenda

• Introduction to IR Camera IQ (Image Quality) Testing
  • Test Items
  • Device Tuning
• Key Points for Improving the User Experience
  • Ambient Light Resistance
  • Auto Exposure
• Consideration of Component Selecting
  • Philosophy of Use
  • Key Components
IR Camera IQ Testing
Test Items

- Test items and detail of test methodology could be updated in the future
- Prerequisites:
  - Test Environment: suggest to leverage the Skype/Lync video test setup, key equipment:
    - 18% Neutral Gray (N5) Metal Wall Panel
    - SFRplus Chart: 24"x34", 5x7, Matte, Two-Tone
    - Frosted 60W incandescent halogen bulbs (A-light) for ambient light evaluation
  - Image Analysis Tool: Imatest® 4.2
  - Define the minimum/maximum distance that camera can support

<table>
<thead>
<tr>
<th>Filter</th>
<th>Frame Pairing</th>
<th>Uniformity</th>
<th>Dynamic Range</th>
<th>IRSNR</th>
<th>MTF 50</th>
<th>MTF Over/Undershoot</th>
<th>Distortion</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 nm+</td>
<td>Yes/No</td>
<td>&lt; 65% @ Max distance</td>
<td>No Saturation min distance</td>
<td>&gt; 30 Full FOV @ Max distance</td>
<td>.35 &gt; MTF &gt; .25 @Max and @Min distance</td>
<td>&lt; 5%/3% @ center @Max and @Min distance</td>
<td>&lt; 5.5%</td>
</tr>
<tr>
<td>Pass</td>
<td>Yes</td>
<td>45%</td>
<td>Pass</td>
<td>33</td>
<td>0.29</td>
<td>0.25</td>
<td>4%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>30</td>
<td>0.25</td>
<td>2.5%</td>
<td>1.0%</td>
</tr>
</tbody>
</table>

- Refer to ISO standards for additional information of test items (listed in Reference)
Filter

Metric:
• 30nm of your wavelength (840~870nm)
• Outside of passband, transmission is < 2%
• Ambient lights with wavelength out of this range should not affect the image at all

Methodology:
• Turning on/off the white LED (Unified Video Test setup, 0~500 Lux), it should cause no difference to the images
• Additional tests might be needed for single sensor solution (RGBIr Hybrid)
Frame Pairing

Metric:
• Each frame pair contains an Illuminated signal capture portion and an ambient capture portion

Methodology:
• Visually verify there are illuminated and unilluminated frames
• For solutions that output frame pairs to Face Authentication pipeline, use “Windows Hello Frame Provider Validation Tool” provided by Microsoft to capture the frames AFTER processed by the IframeProvider. Then verify there are illuminated and unilluminated frames
Uniformity

Metric:
- **Illumination light shall be distributed so the Relative illumination on the sensor does not fall below 35% of the Peak Value**

Methodology:
- Capture image of the 18% Neutral Gray (N5) Metal Wall Panel (Unified Video Test setup) at maximum supported distance
- Use the built in IR LED as the only illumination
- Corner with width of 20 pixel can be ignored
- Intensity of worst corner needs to be above 35% (total drop off can not be over 65%)
Uniformity

**Imatest analysis steps**
Dynamic Range

Metric:
• @ min distance will not saturate skin (60% diffuse reflectivity)
• @ max distance satisfy IRSNR requirement

Methodology:
• Dynamic range should be tested with High Ambient and No Ambient conditions.
• Image should not be saturated with high ambient at minimum range.
• Capture image of the SFRPlus (put the step chart in the center) at minimum operating distance
Dynamic Range

- Simulating the human skin with:
  - Patch #12 to #16 of the step chart (Zone #5 to zone #9 in the summary sheet)

- Gray level of zone #5 should not exceed 255, and remain linear difference to #4 and #6
IR SNR

Metric:
• 30 over the entire FOV

Methodology:
• Built in IR LED as the only illumination source; take image of the step chart of the SFRPlus
• Test with no ambient light and ambient light conditions
• Measure the SNR with the ambient subtracted image
• SNR should be measured at the center and corner (or any possibly worse area 50 pixels inward from the boarder) of the image
• Specifically looking at the SNR of zone #9
IR SNR

Imatest analysis steps
MTF (Modulation Transfer Function)

Metric:
• 0.35 cycles/pixel > MTF50 > 0.25 cycles/pixel at minimum and maximum range

Methodology:
• Apply sufficient IR illumination to the chart (e.g. A-light); take image of the slant square of the SFRPlus
• MTF should be measured at the center and corner (or any possibly worse area of the entire FOV) of the image
• Calculating 4 edges of the slant square, and record the lowest
MTF Overshoot/Undershoot

Metric:
- Image enhancement algorithm should not be applied too aggressively

Methodology:
- Generate the edge profile plot while measuring the MTF at center of the FOV
- Overshoot/undershoot of the edge profile cannot exceed 5%/3%

Side effects of enhancement filter that could impact face recognition:
- Grainy image
- False contour
MTF & Over/Undershoot

**Imatest analysis steps**

![Imatest analysis steps](image-url)
Distortion

- **TV distortion < 5.5%**
- **Methodology:**
  - Capture image of the full SFRplus chart
  - Apply external IR illumination if necessary to achieve sufficient brightness (e.g. A-light, incandescent halogen light)
Distortion

**Imatest analysis steps**
Filter (for Single Sensor Solution)

- For RGBIr hybrid (single sensor) solution, non-IR lights should not cause obvious brightness change on the IR image.
- Non-IR light should not cause shading or bright/dark spots on the image.
- When camera operating in the high IR ambient illuminated environment, it should still maintain the image quality:
  - Unlike dual sensor solution which can physically block all the non-IR, single sensor solution may need to adjust the exposure to avoid both IR and visible lights from saturating the sensor, which means the dynamic range of IR signal would be compressed if strong visible lights present.
Filter (for Single Sensor Solution)

40 lux non-IR ambient  
350 lux non-IR ambient  
Cancelation failure
Filter (for Single Sensor Solution)

• Run the IQ tests under different non-IR ambient conditions
• Methodology:
  • Rerun SNR/MTF (including over/undershoot) test under white LED (3000K, Unified Video test setup): 0, 100, 500, 1000 lux, requirements should still be met. (If not leveraging the illumination system of Unified Video Test setup, any compleitive illuminating equipment cooperate with lux meter is acceptable.)
  • Capture human face images with operating distance under conditions above, there should not be significant differences on face images
Parameters That Impact The IQ

- **Uniformity**
  Affected by: IR LED radiation characteristics, lens shading

- **SNR**
  Affected by: IR LED intensity, lens shading, sensor noise

- **MTF**
  Affected by: IR LED intensity, lens shading, lens IQ
Device Tuning

Firmware tuning
- Lens shading correction
- Slight image enhancement
- Sensor configuration tuning

Hardware change
- Camera component
- LED current supply adjustment

Image cropping
- Crop the output image, so invalid area would not be provide to Face Authentication platform
  (Image cannot be smaller than 340x340 pixels)
Improving the User Experience
Methodology:

- Use paired frame to run the SNR/MTF (including over/undershot) test item under different intensity of ambient IR, the result should still meet the requirements.
- Capture human face image with the DUT under different intensity of ambient IR, there should not have **noise, unnatural pattern, oversharpening, false contour** appearance while the ambient IR intensity is increased.
- Recommended IR ambient source: **incandescent bulb, A-light (Unified video test setup), sunlight**. When testing, refer to the following table for levels of ambient light intensity.

<table>
<thead>
<tr>
<th>Scenario:</th>
<th>Indoor</th>
<th>Indoor w/ Incandescent or Halogen Light</th>
<th>Indoor Office Next to Window</th>
<th>Outdoor Cloudy</th>
<th>Outdoor Sunny in Shade</th>
<th>Outdoor Sunshine</th>
<th>Outdoor Sunshine on sensor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Light Level (Lux)</td>
<td>50</td>
<td>500</td>
<td>700</td>
<td>1000</td>
<td>1000</td>
<td>10,000</td>
<td>10,000</td>
</tr>
</tbody>
</table>
Ambient IR Resistance

- Frame pairing (subtraction) for ambient IR canceling
- Gamma = 1
  Gray level of pixel need to linearly respond to object brightness
Ambient IR Resistance

- Condition: Indoor, fluorescent light from top
- Issue – **failure of ambient IR cancelation**
  - Unnatural black shade on the shoulder
  - Noise like black pixels in the background
- Root cause: gamma≠1 (camera is more sensitive at non-illuminated frame than illuminated frame)
Auto Exposure

• Recommend human face brightness
  • 80~150 pixel gray level (100 is the best)

• Typical scenario
  • Wall (or other objects) is far away from the face – black background
  • Wall close to user – gray/bright background

• Challenged scenario
  • Sunlight (window)
  • Intense IR ambient light (e.g. halogen lamp)
Example of good Images

- Face is evenly illuminated, proper exposure.
- Illuminator cast natural shading on face, face has proper contrast, the gradient provides rich information about face 3d shape.
- Face feels natural looking, no over smoothing or over sharpening.
Example of Problematic Images

- Too much processing on both smooth and sharpening lost detail, make face feels grainy, impose artificial edges on face.
- Ambient light subtraction improperly applied when there is strong environment light on one side of face, result image appears high noise, improper dark region on right side.
- Strange edges from motion blur, result of slow frame rate and pixel by pixel simple ambient light subtraction.
- Face is over exposed in the center, lots saturated pixels.
Consideration of Component Selecting
Philosophy of Use

- Based on the form factor of device: tablet/laptop/desktop, decide the key factors:
  - **Minimum** operation distance
    Notebook/Tablet: 30cm
    Desktop: 30cm
    Mobile (Phone): 20cm
  - **Maximum** operation distance
    Laptop/Tablet: 75cm
    Desktop: 100cm
    Mobile (Phone): 45cm
  - **FOV** (Field of View)
    >= 40° horizontal, >= 45° vertical
    It will impact the user experience if the FOV is too small. Moreover, in the output image, human face needs to be away from the boarder more than 1/10 of the face width.

- **Example:**
  - Form factor: **Tablet**
  - Operating distance: **30~75 cm**
  - FOV: **50°** horizontal/vertical (covered 28 x 28 cm at 30 cm distance)
Choose Your Components Wisely

• Consider these three critical items when choosing your camera components
  • **Uniformity**
    Affected by: IR LED radiation characteristics, Lens RI (Relative Illumination)
  • **SNR**
    Affected by: IR LED intensity, Lens RI, sensor noise
  • **MTF**
    Affected by: IR LED intensity, Lens RI, Lens IQ
• Key Factors of components
  • **LED**
    Radiation characteristics, Intensity
  • **LENS**
    Lens RI (Relative Illumination), Lens IQ
SENSOR

- **Recommended use of** global shutter **sensor**
  - Needs to meet **30 sensor fps** and **340 x 340** pixel of image size after cropping.
- **Rolling Shutter Issues**
  - **Exposure Uniformity** - ensure frames (either illuminated or ambient) are not partially illuminated by IR LED.
  - **Banding** – especially problematic for tablets / mobile devices where screen orientation can be rotated.
  - **Bandwidth management** – needs to meet **60 sensor fps** so camera can provide **15 effective frame pairs** per second. Minimum resolution is **340 x 340** pixel after cropping (if necessary).
  - **Signal intensity** - due to short exposure time, good sensitivity and low noise are critical for rolling shutter sensor, as well as sufficient LED illuminating.
LED

- The illumination better be focus to the target FOV and uniform within the target FOV, the ideal characteristic curve (for 60°) are shown in red line
- Key parameters
  - **Power of LED**
    Intensity of illumination will directly impact the image quality, also the capability of ambient IR resistant
  - **Radiation Characteristics**
    Affect the final image brightness uniformity, and the MTF/SNR at the corner of image
LED

Other example of Radiation Characteristics
LED

- Drop off of illumination intensity due to distance & brightness (30° half-FOV for example)
  
  \[
  \text{Distance} = \sqrt{3} : \sqrt{5} \\
  \text{Distance}^2 = 3 : 5 \\
  0.6 \times 0.85 (\text{LED intensity}) = 51\% \text{ (energy to camera)}
  \]

(In real situation, the uniformity is lot worse than this value due to **lens shading**)

- 80% LED intensity within target FOV should be sufficient.
- LED uniformity higher than 80% is nice to have, but overall intensity and energy focusing would be more important
Lens

- **F/No**
  - With only the LED for illuminating, it is considered low light condition
- **Relative Illumination (RI) and Image Circle Diameter**
  - Directly impact the final image brightness uniformity

- **Lens shading correction**
  - Necessary to achieve uniformity requirement
  - It does not improve the image quality (SNR/MTF)
  - Overly rely on lens shading would cause problem on auto-exposure and ambient IR resistance.
Appendix and Reference
Windows Hello Frame Provider Validation Tool

Validations:
- Provider Properties
- Frame Properties
- Image Analysis
- Face Detection

(Please refer to the user guide for detail)
## Equipment list

<table>
<thead>
<tr>
<th>Item</th>
<th>Reference/link</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light stand with Frosted 60W incandescent halogen bulb</td>
<td>Philips PHE27-70W</td>
</tr>
<tr>
<td>Distance Meter</td>
<td><a href="http://www.pcstore.com.tw/udtoolnet/M09225875.htm">http://www.pcstore.com.tw/udtoolnet/M09225875.htm</a></td>
</tr>
</tbody>
</table>
Reference

- Windows Hardware Guidance for Delightful Authentication Scenario
- Imatest guidance: http://www.imatest.com/docs/
- Additional Test Item References:
  - MTF: ISO-12233
  - Dynamic Range: ISO-15739
  - IRSNR (Daylight): ISO-15739
  - Stray Light (Veiling Glare): ISO-9358