Microsoft

Face Authentication Device Testing

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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

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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

Filter	Frame Pairing	Uniformity	Dynamic Range	IRSNR		MTF 50		MTF Over/Undershoot		Distortion
30 nm+-	Yes/No	< 65% @ Max distance	No Saturation min distance	> 30 Full FOV @ Max distance		.35>MTF>.25 @Max and @Min distance		< 5%/3% @ center @Max and @Min distance		< 5.5%
				Center	Corner	Center	Corner	Overshoot	Undershoot	
Pass	Yes	45%	Pass	33	30	0.29	0.25	4%	2.5%	1.0%

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

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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)

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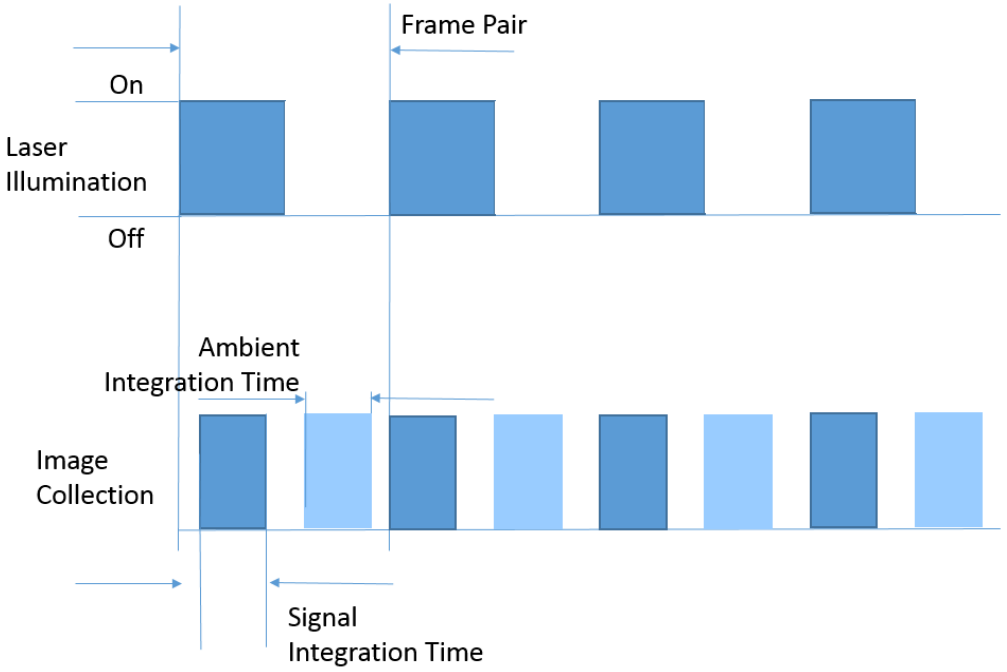
Frame Pairing

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



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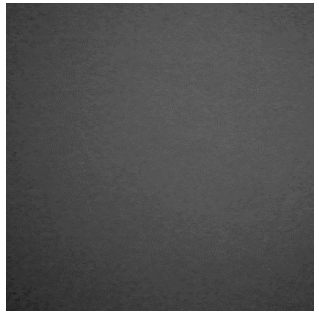
Uniformity

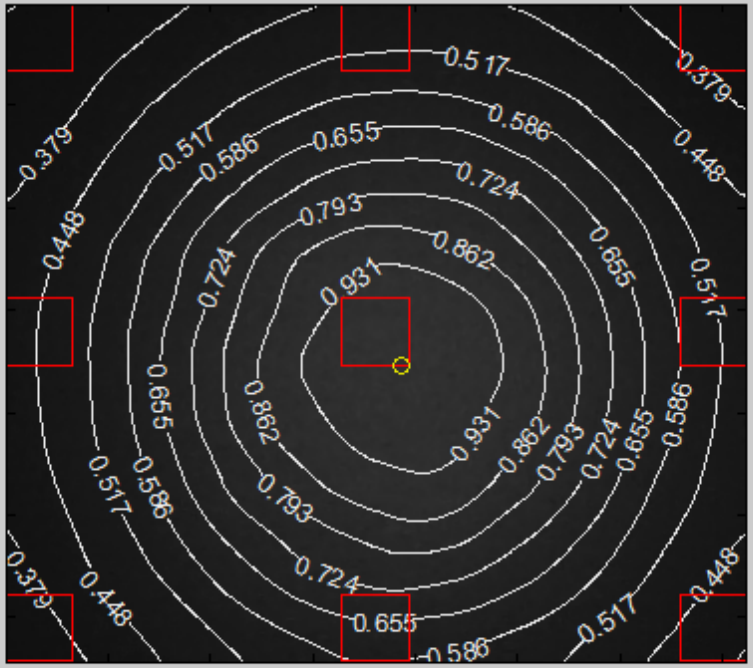
Metric:

- 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%)





Max = 0.192 (relative to 1 for pixel 255) [32x32 pxls areas]
Corners: worst = 0.0625 (32.6%); mean = 0.0696 (36.3%)
Sides: 0.0867 (45.2%) 0.101 (52.7%); mean = 48.9%

L R T B = 0.0867 0.101 0.0954 0.123
UL LL UR LR = 0.0625 0.0696 0.0681 0.0784

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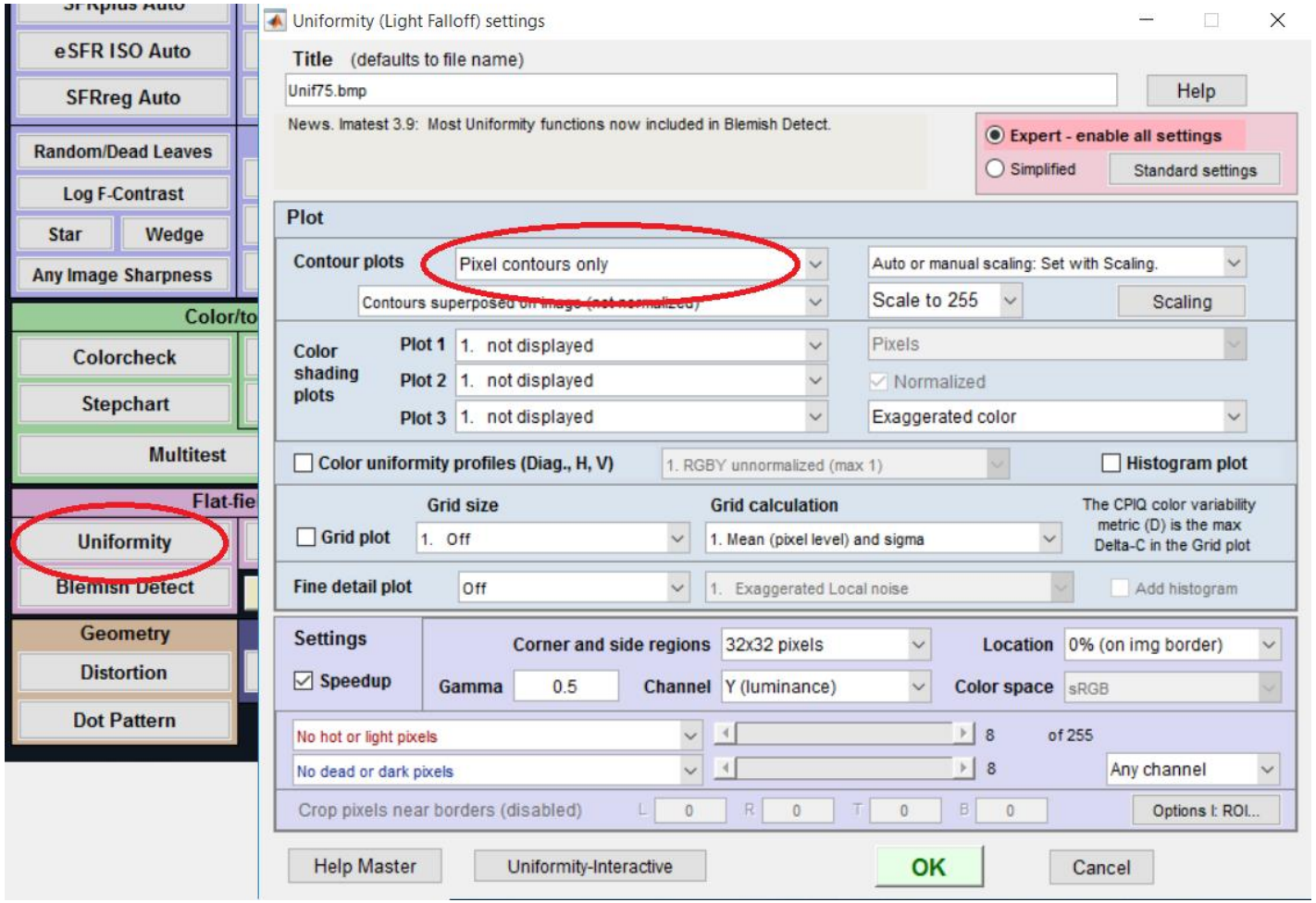
Uniformity

Imatest analysis steps



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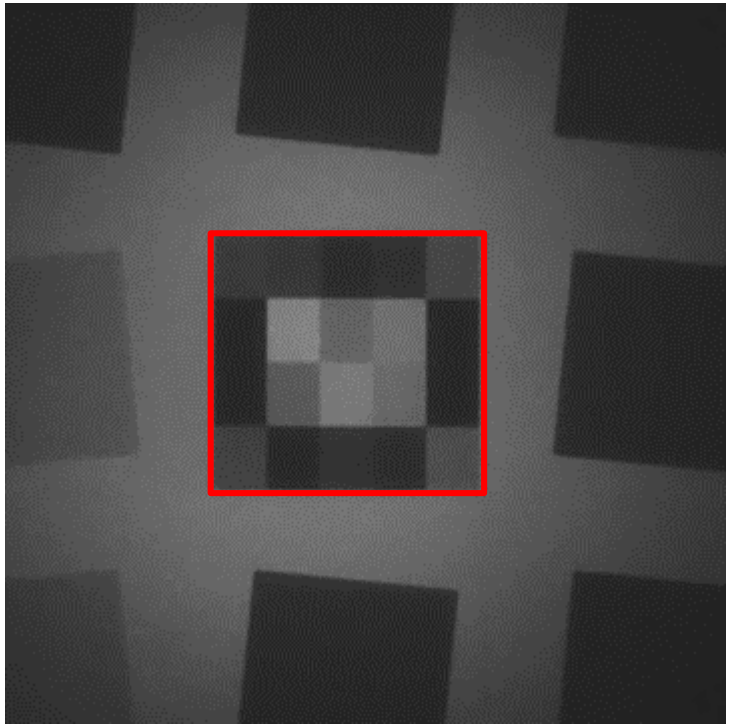
Dynamic Range

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



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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

11	Zone	Pixel	Pixel/255	Log(exp)	Log(px/25	Lux (patch)
12	1	155.2	0.6086	-0.05	-0.2156	
13	2	148.6	0.5829	-0.15	-0.2344	
14	3	137.2	0.5379	-0.25	-0.2693	
15	4	129.8	0.5089	-0.35	-0.2934	
16	5	115.6	0.4535	-0.45	-0.3434	
17	6	107.3	0.4208	-0.55	-0.3759	
18	7	107.2	0.4203	-0.65	-0.3764	
19	8	88	0.3449	-0.75	-0.4623	
20	9	80	0.3136	-0.85	-0.5036	
21	10	63.6	0.2496	-0.95	-0.6028	
22	11	52.5	0.2058	-1.05	-0.6866	
23	12	48	0.1883	-1.15	-0.7251	
24	13	39.8	0.1561	-1.25	-0.8066	
25	14	38.5	0.151	-1.35	-0.821	
26	15	28.3	0.1112	-1.45	-0.9541	
27	16	26.4	0.1034	-1.55	-0.9854	
28	17	24.5	0.0962	-1.65	-1.0168	
29	18	25.7	0.1007	-1.75	-0.9969	
30	19	24	0.094	-1.85	-1.0271	
31	20	24.8	0.0974	-1.95	-1.0115	

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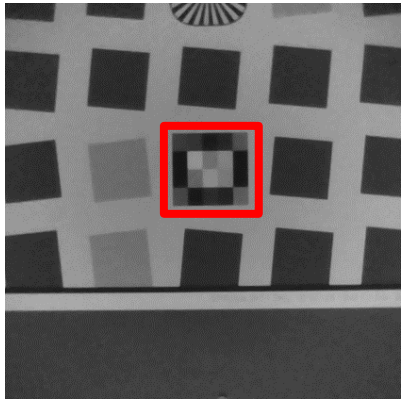
IR SNR

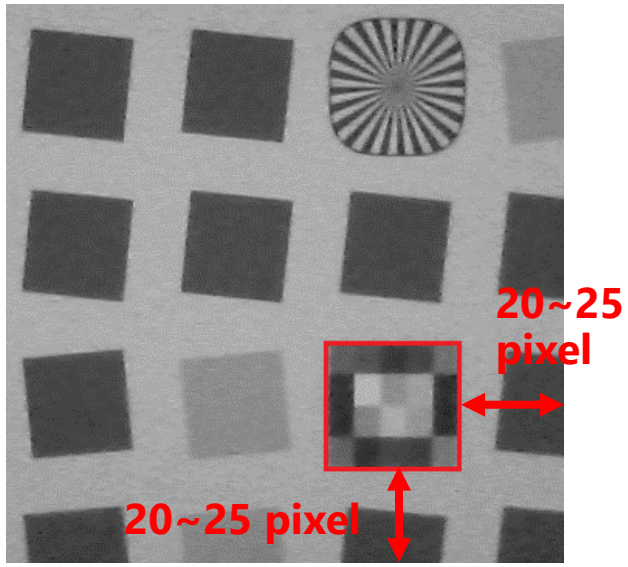
Metric:

- 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





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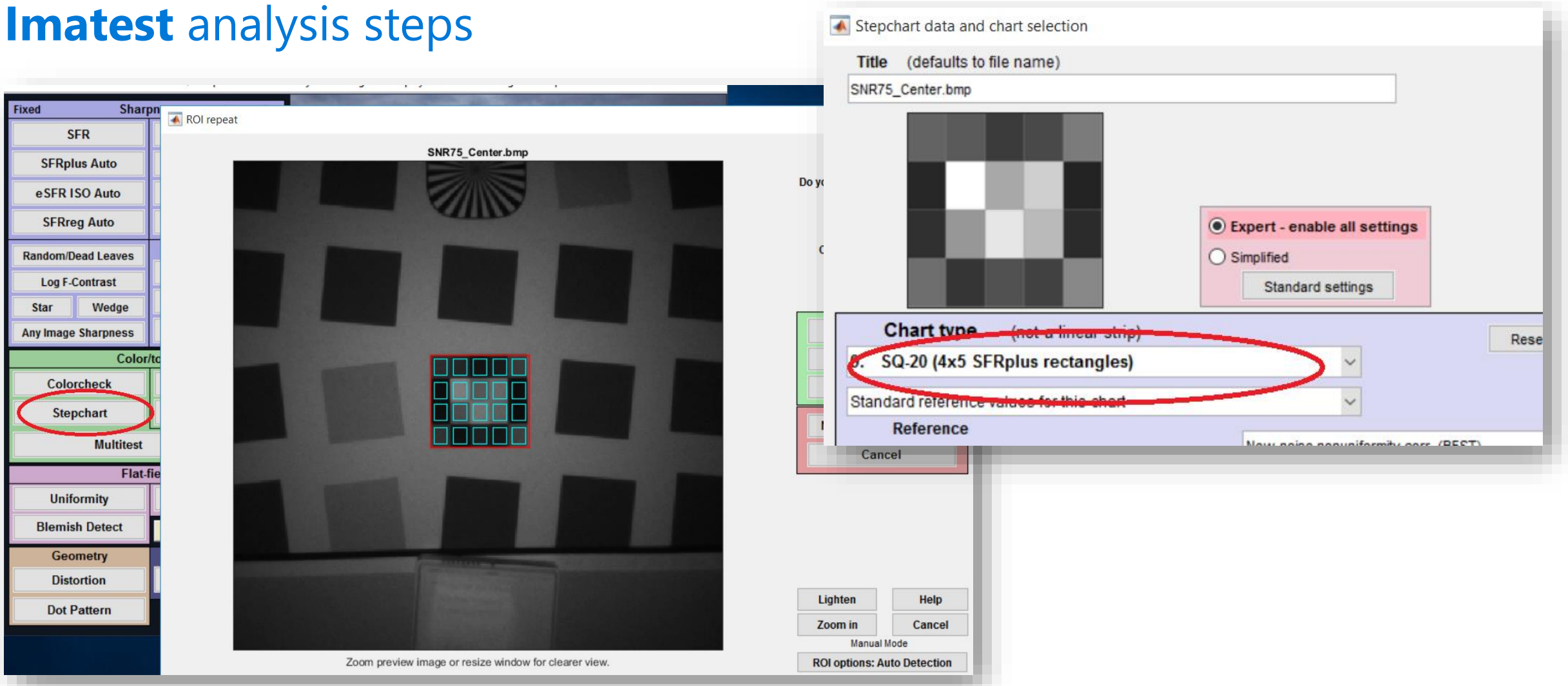
IR SNR

Imatest analysis steps



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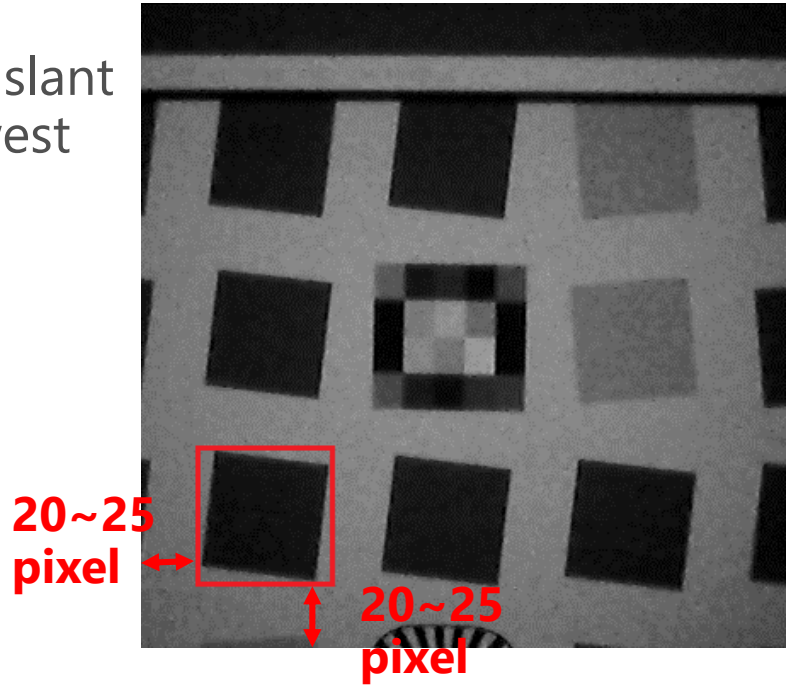
MTF (Modulation Transfer Function)

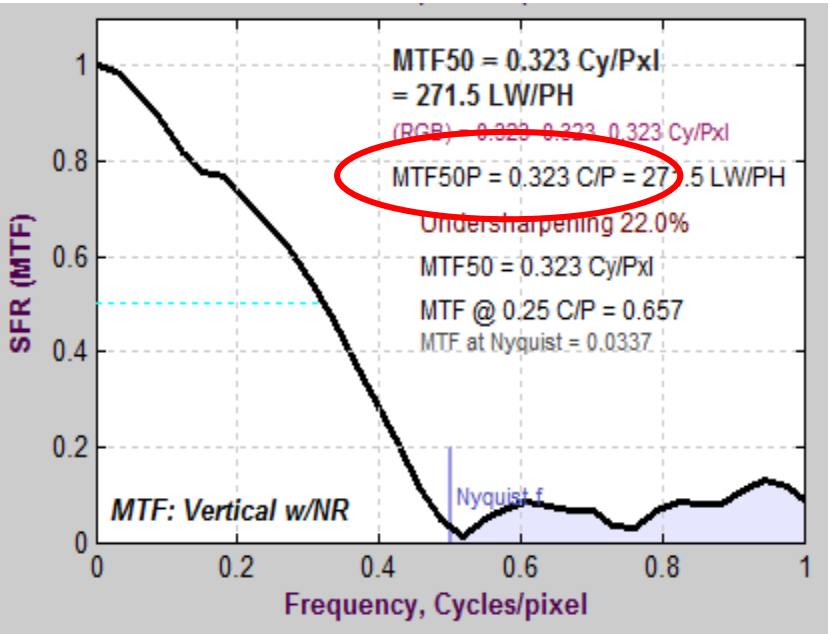
Metric:

- 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





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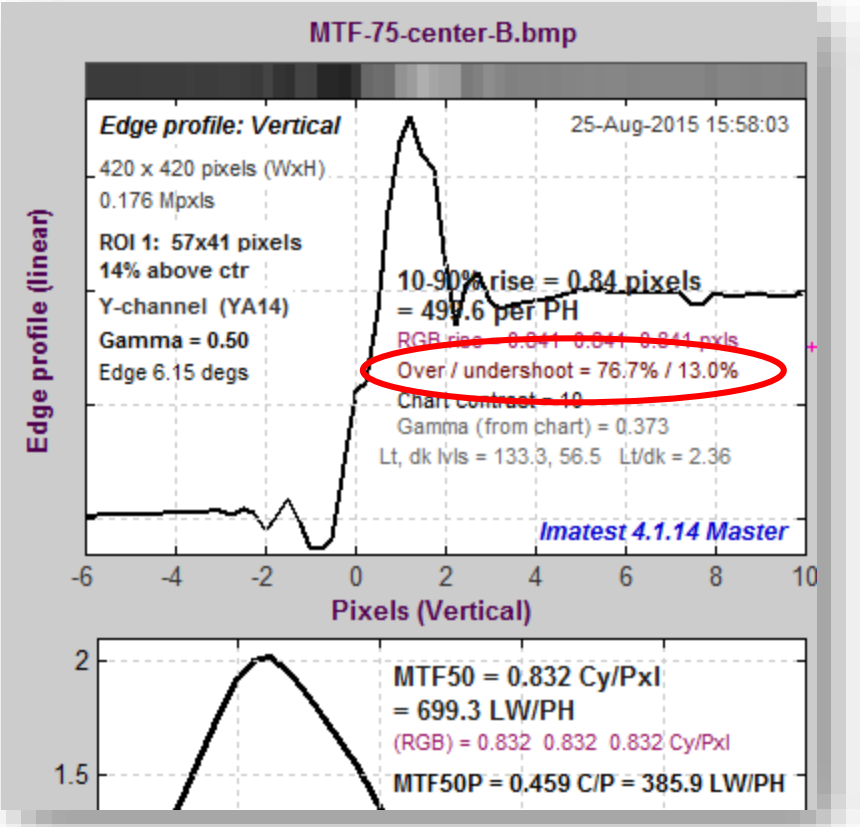
MTF Overshoot/Undershoot

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

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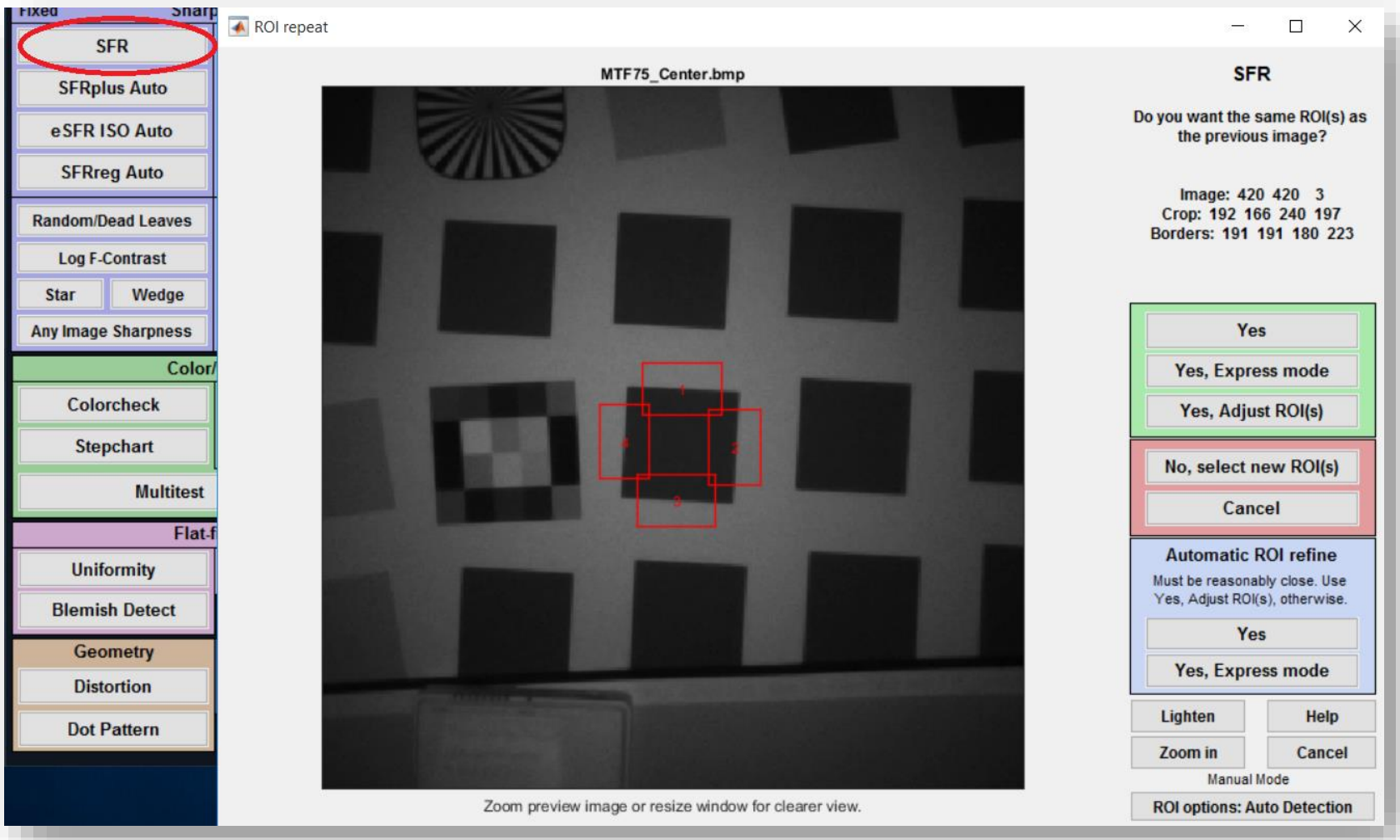
MTF & Over/Undershoot

Imatest analysis steps



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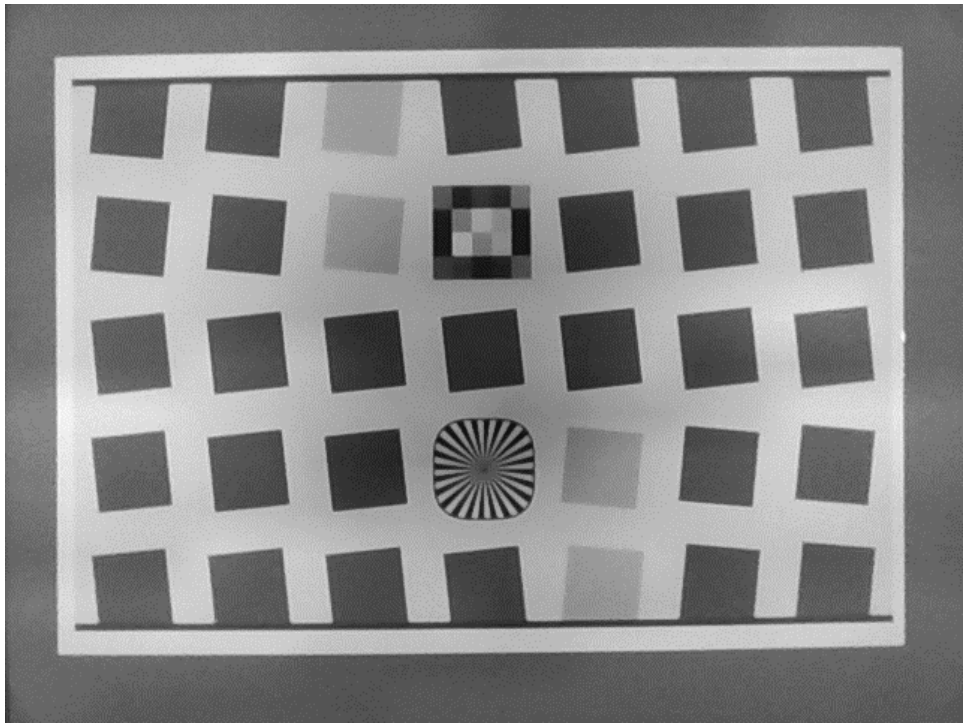
Distortion

- 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)



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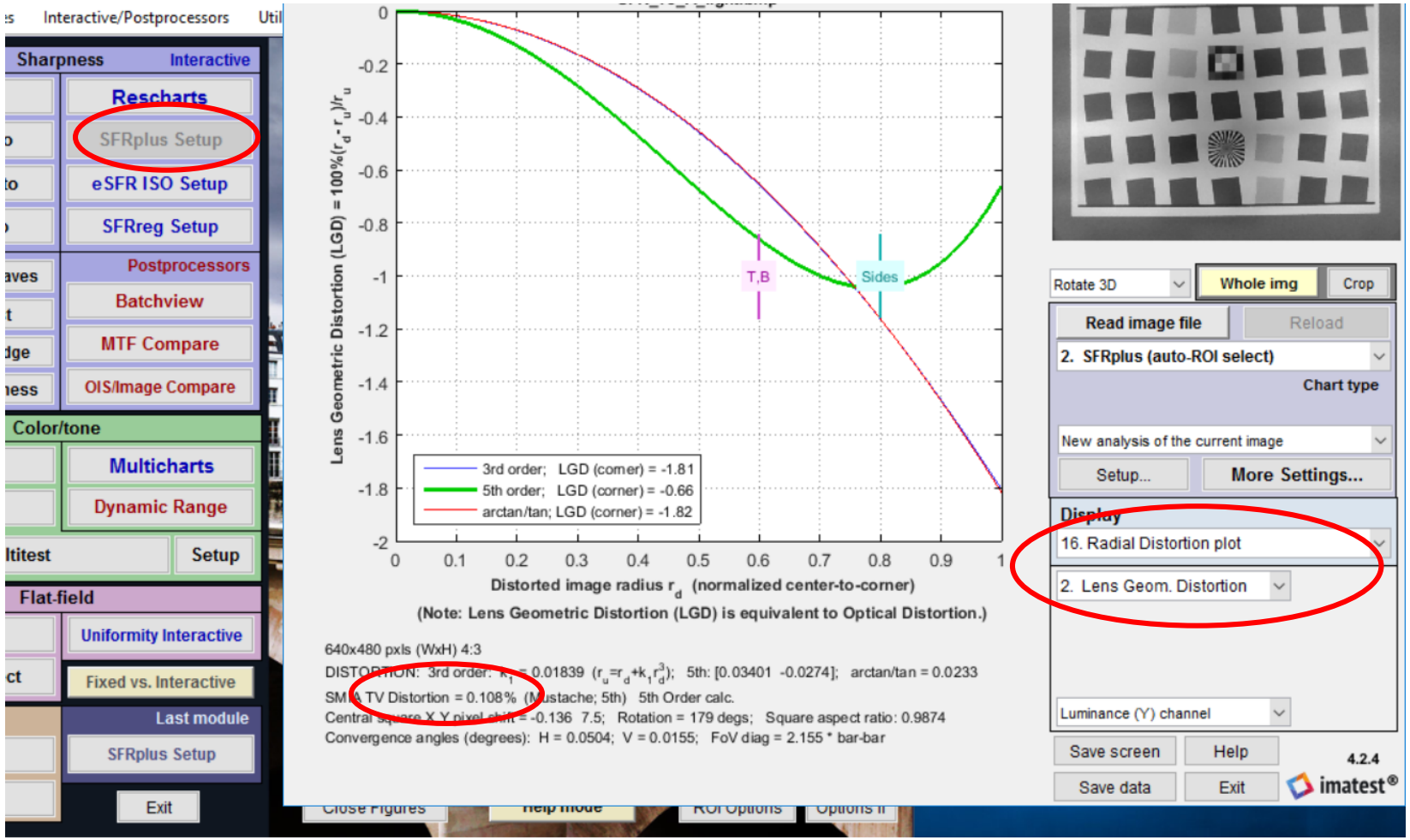
Distortion

Imatest analysis steps



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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

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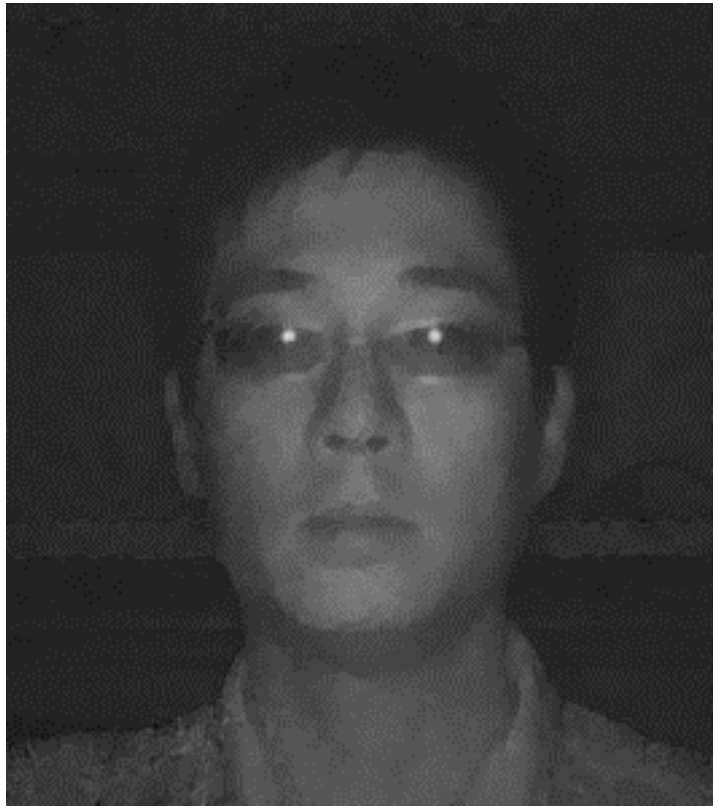
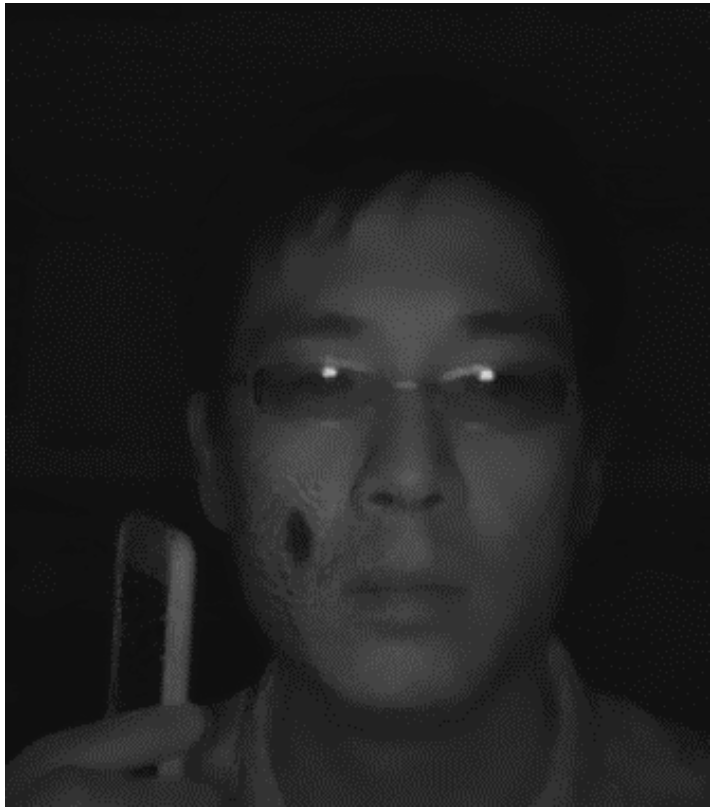
Filter (for Single Sensor Solution)

40 lux non-IR ambient



350 lux non-IR ambient



Cancelation failure

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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 completive 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

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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

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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)

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Improving the User Experience

Ambient IR Resistance

For frame pairing, leveraging Microsoft inbox mechanism is recommended, if manufactures use their own pairing algorithm, the following tests are required

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.

Scenario:	Indoor	Indoor w/ Incandescent or Halogen Light	Indoor Office Next to Window	Outdoor Cloudy	Outdoor Sunny in Shade	Outdoor Sunshine	Outdoor Sunshine on sensor
Average Light Level (Lux)	50	500	700	1000	1000	10,000	10,000

Required Operating Range

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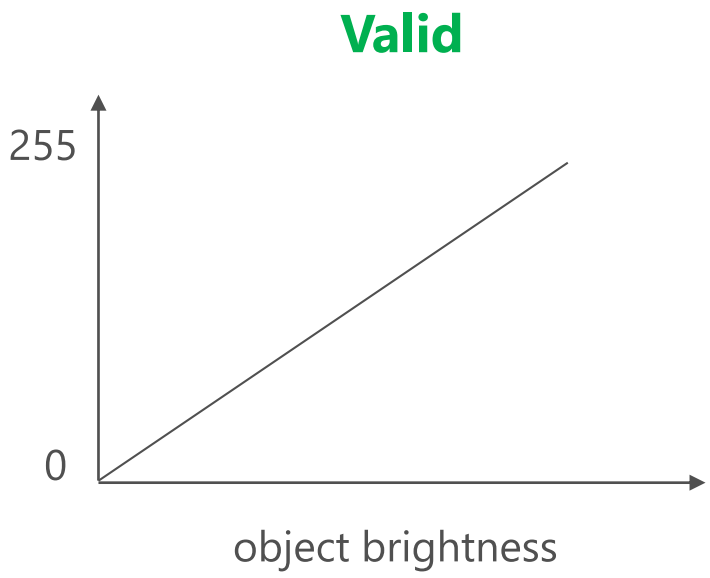
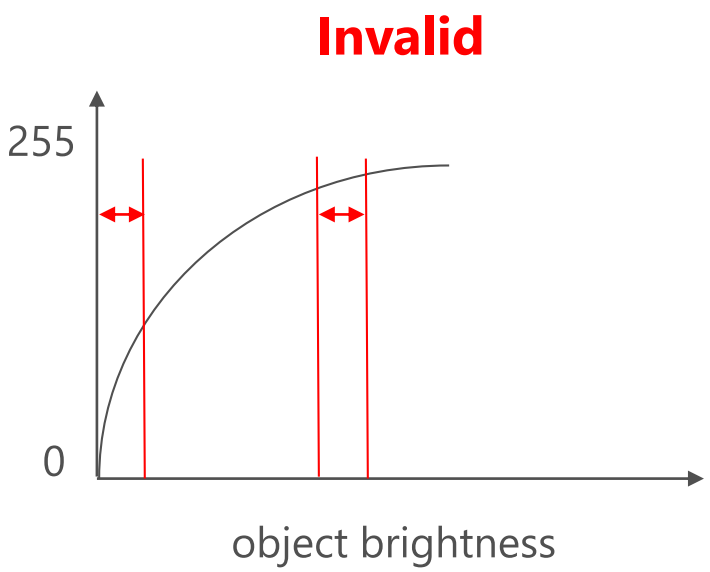
Ambient IR Resistance

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





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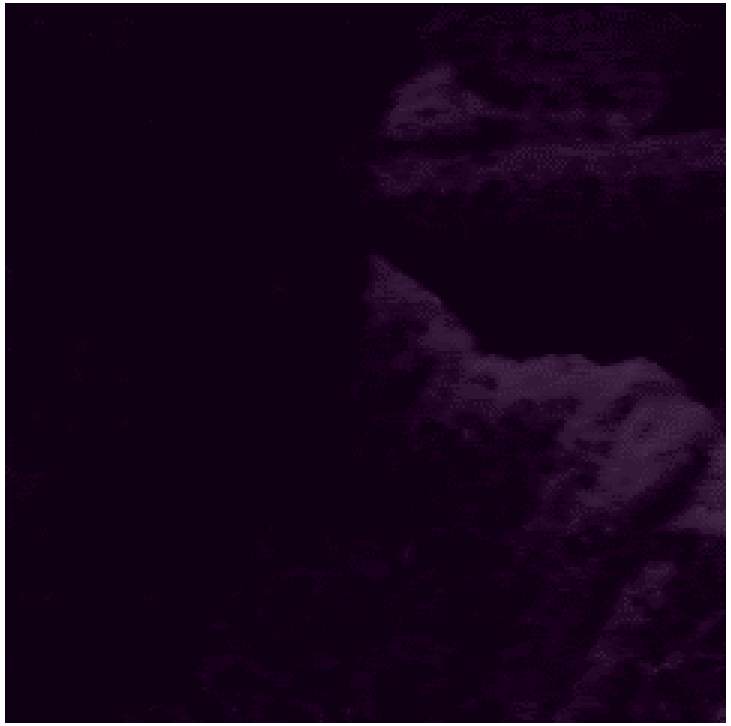
Ambient IR Resistance

- 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)



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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)

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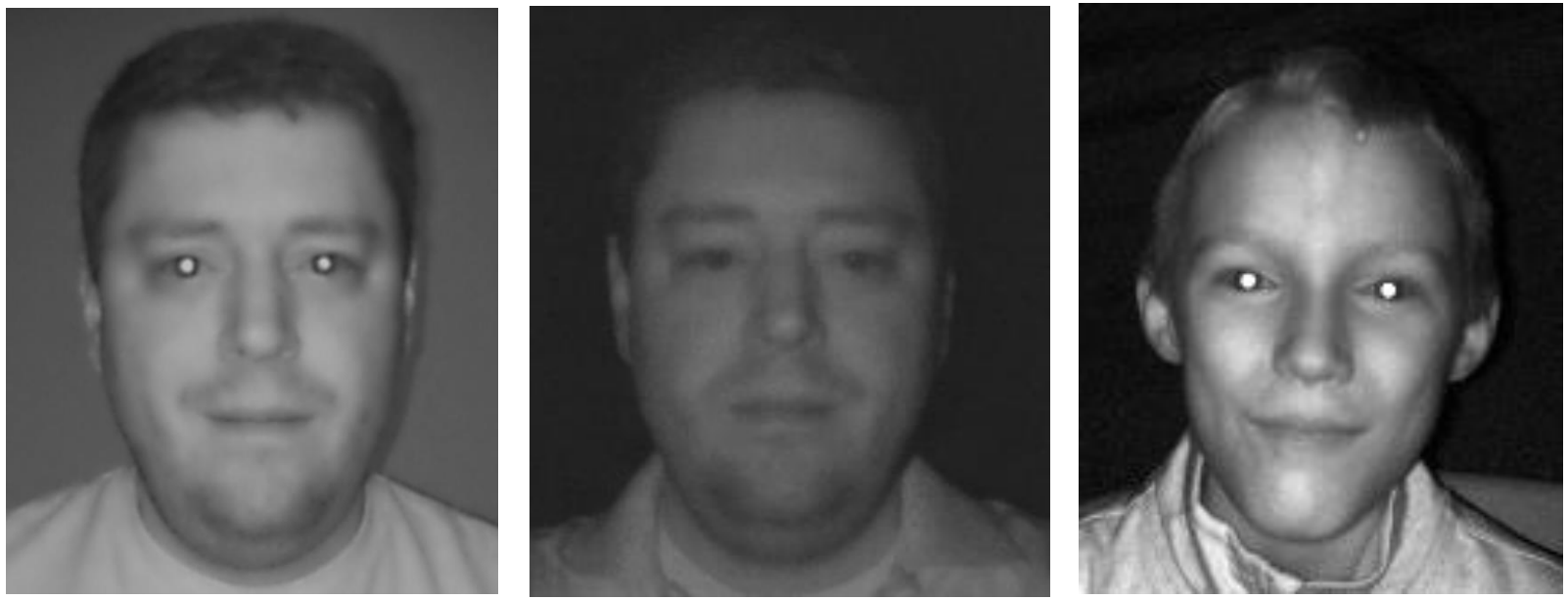
Example of good Images

- 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.



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Example of Problematic Images

Too 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.

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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)

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Choose Your Components Wisely

- Consider these three critical item 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

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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.

Example of image with banding issue

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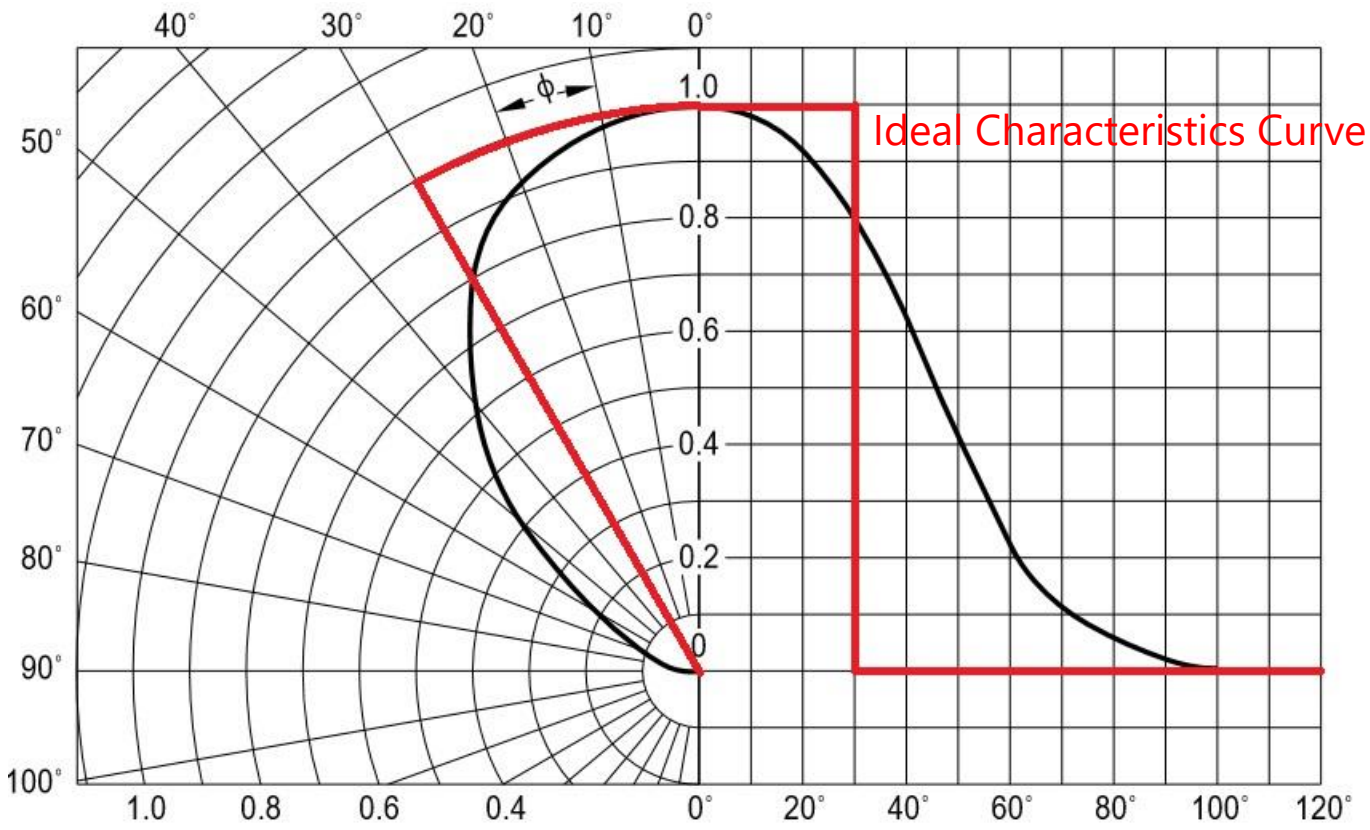
LED

- 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



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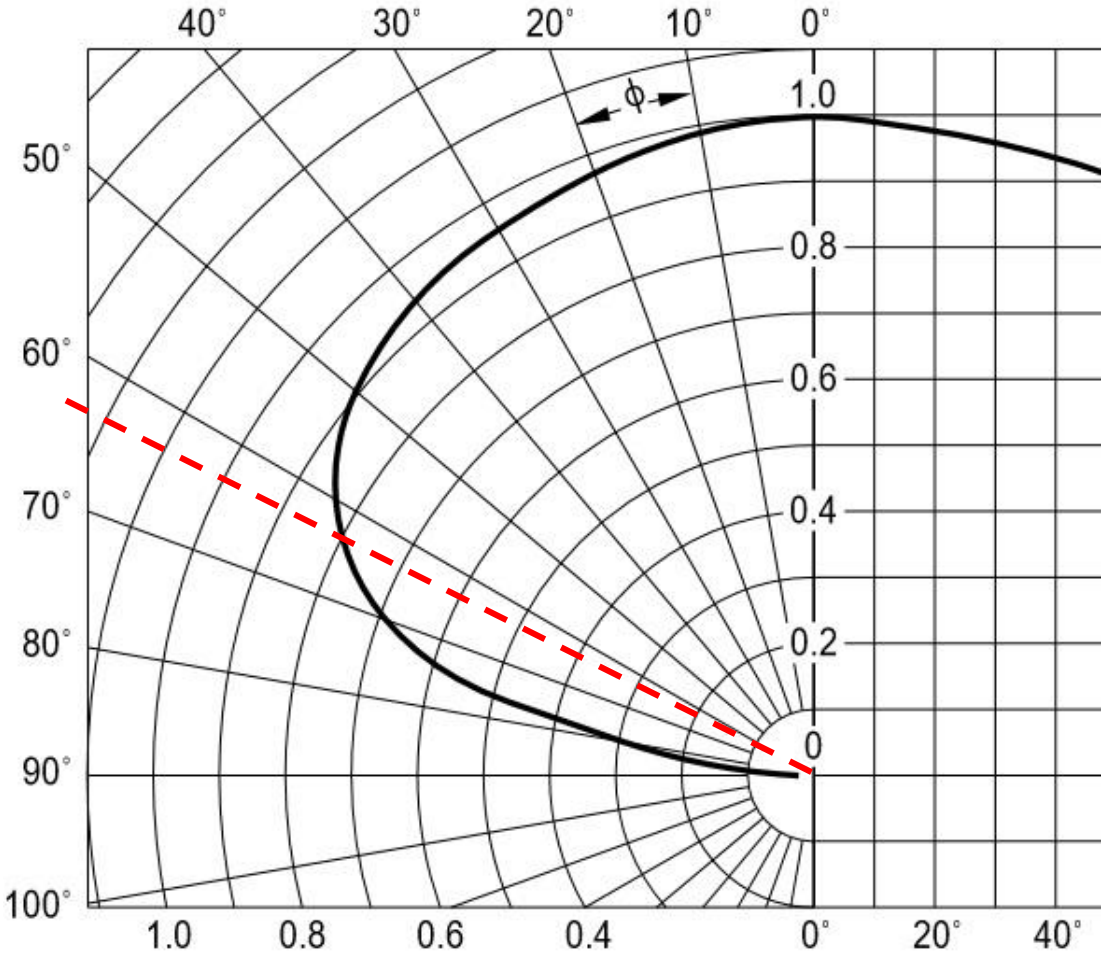
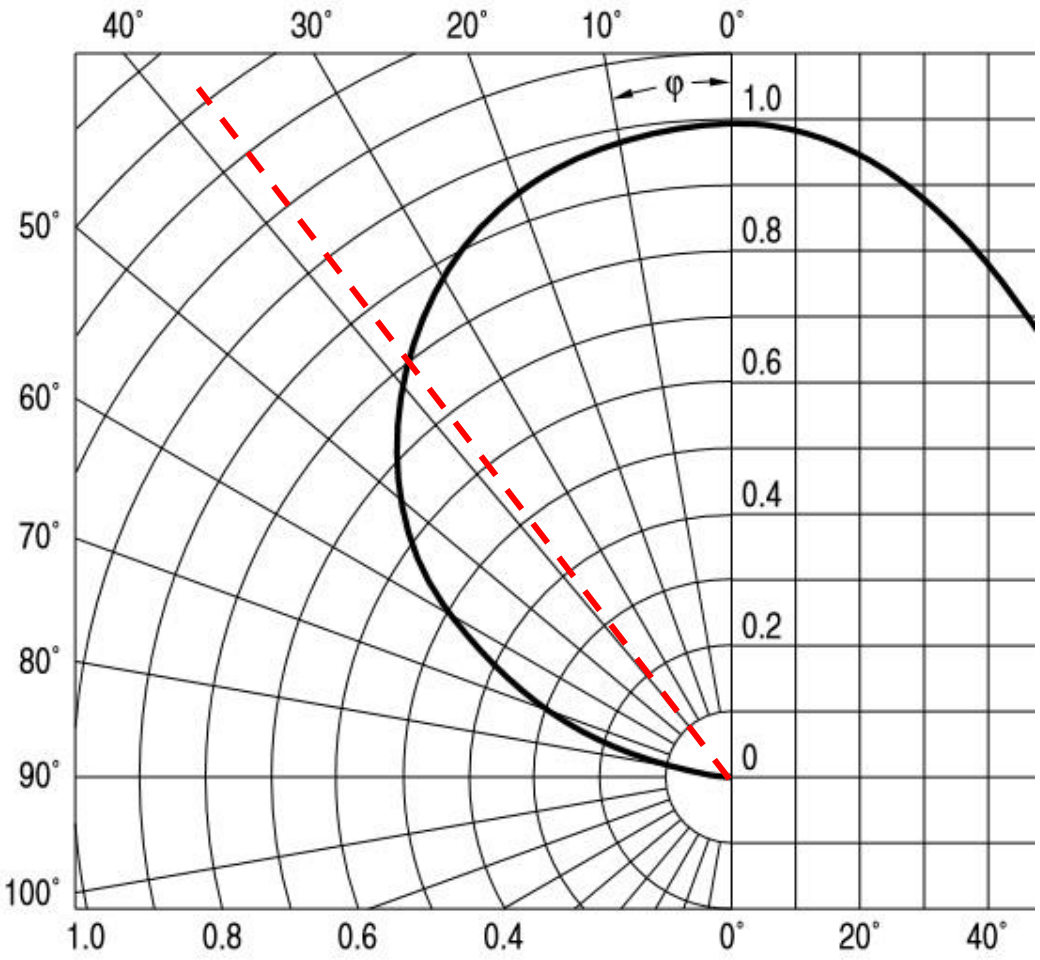
LED

Other example of Radiation Characteristics





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LED

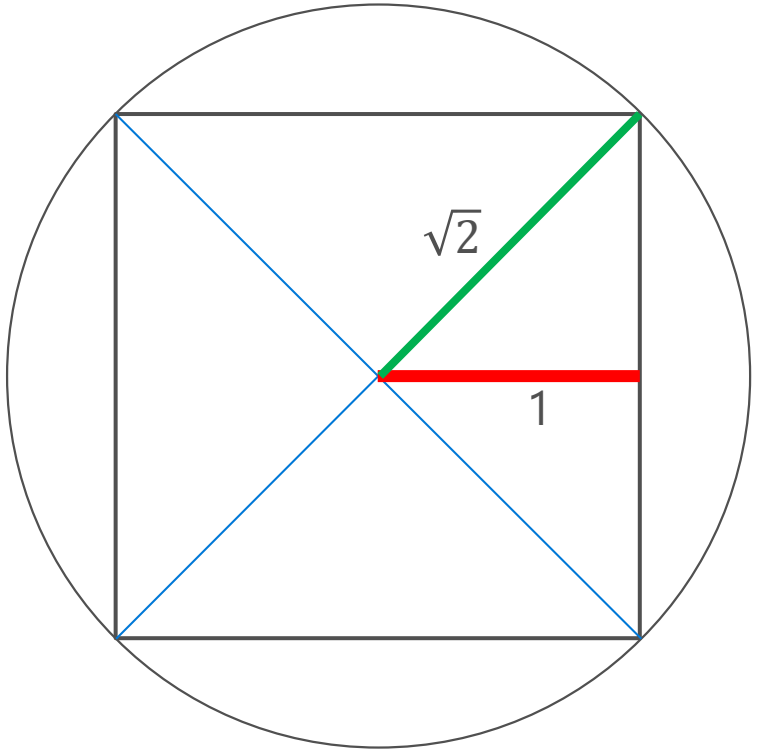
- Drop off of illumination intensity due to distance & brightness (30° half-FOV for example)

  Distance = $\sqrt{3} : \sqrt{5}$

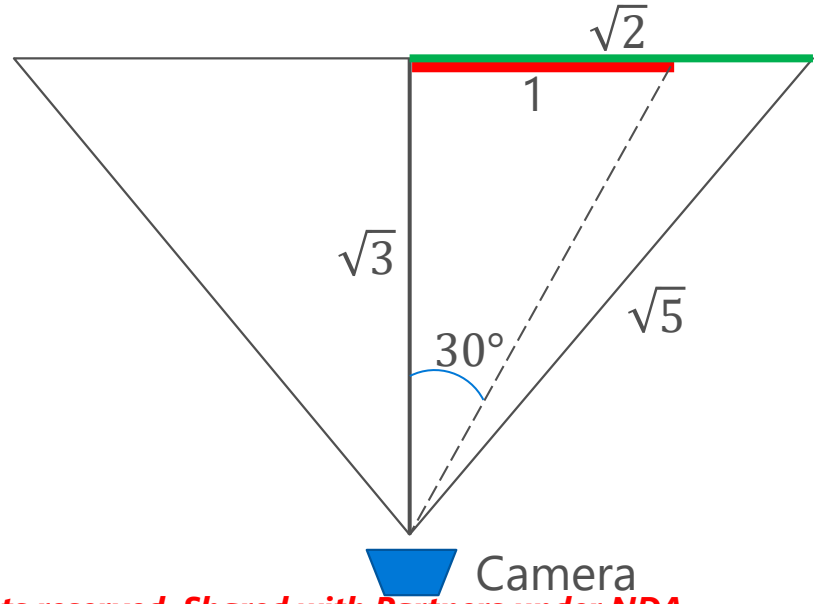
  Distance^2 = 3 : 5

  0.6 x 0.85 (LED intensity) = **51%** (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



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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 relay on lens shading would cause problem on auto-exposure and ambient IR resistance.

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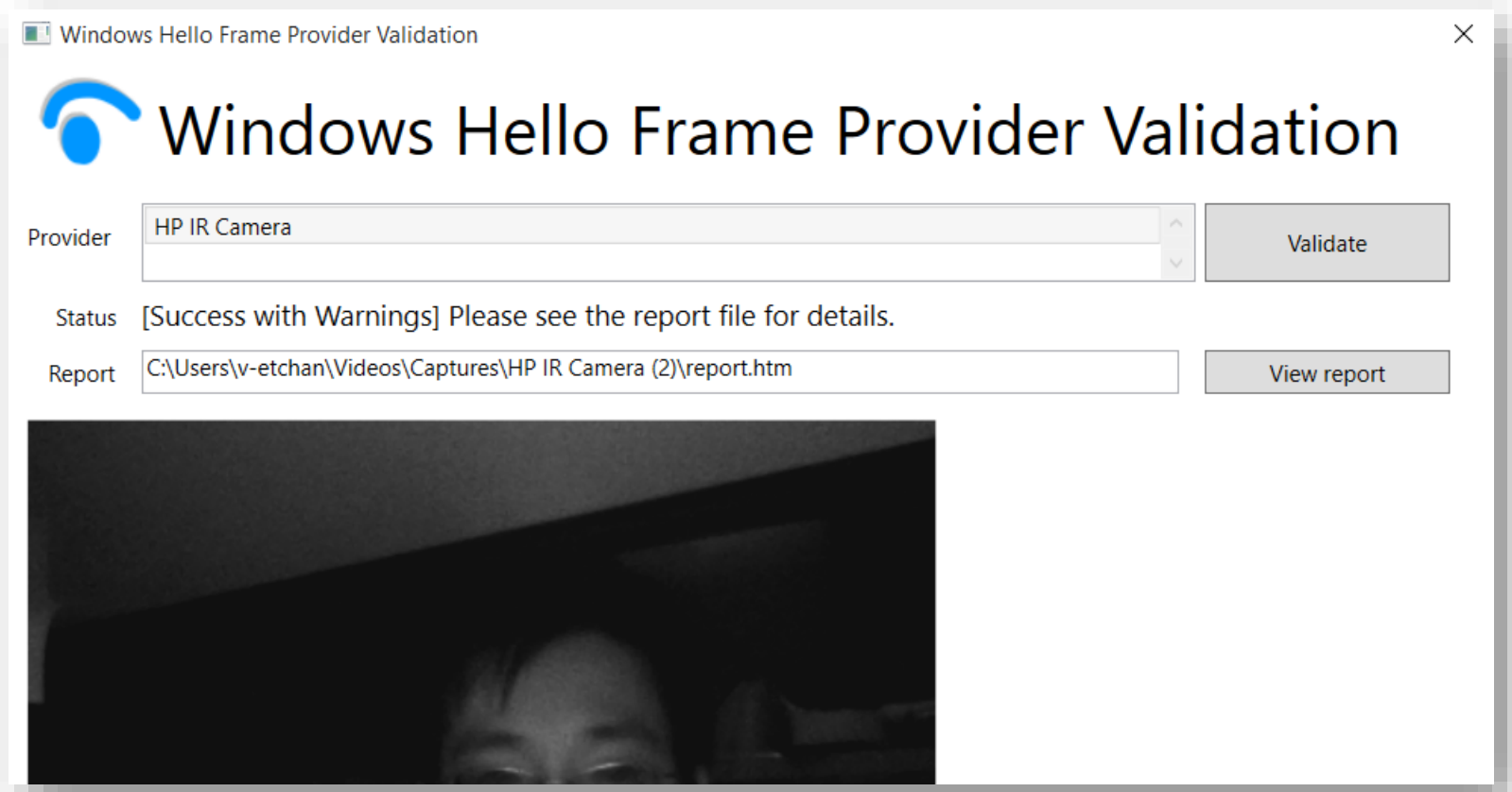
Appendix and Reference

Windows Hello Frame Provider Validation Tool

Validations:

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

(Please refer to the user guide for detail)



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Appendix

Equipment list

Item	Reference/link
18% Neutral Gray (N5) Metal Wall Panel	http://www.imagequalitylabs.com/product_details/41
SFRplus Chart: 24"x34", 5x7, Matte, Two-Tone	http://www.dhdcolor.com.tw/index.php?route=product/product&path=107_108&product_id=968
Light stand with Frosted 60W incandescent halogen bulb	Philips PHE27-70W
Imatest	http://www.imatest.com/products/
Lux Meter	http://www.inss.com.tw/ep-3.htm
Distance Meter	http://www.pcstore.com.tw/udtoolnet/M09225875.htm
Windows Hello Frame Provider Validation Tool	https://connect.microsoft.com/site1304/Downloads/DownloadDetails.aspx?DownloadID=59313

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Reference

- Windows Hardware Guidance for Delightful Authentication Scenario
- Imatest guidance: http://www.imatest.com/docs/
- Skype & Lync Video Capture Specification: https://technet.microsoft.com/en-us/office/dn788953.aspx
- Additional Test Item References:
  - MTF: ISO-12233
  - Dynamic Range: ISO-15739
  - IRSNR (Daylight): ISO-15739
  - Stray Light (Veiling Glare): ISO-9358

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