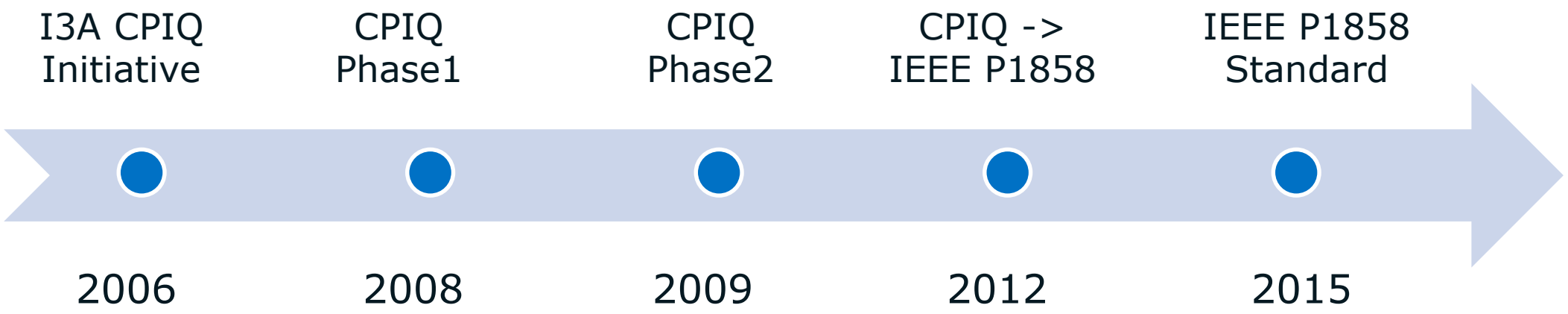
# IEEE CPIQ Standard Updates

Elaine Jin and Philip Corriveau
Intel Corporation
September 14, 2015

# CPIQ Standard Timeline




IEEE P1858 CPIQ Standard is currently under ballot review, with a planned release in 2016.

# CPIQ Membership

- The IEEE CPIQ members include:
  - telecom carriers
  - operating-system vendors
  - chipset vendors
  - network equipment vendors
  - mobile device vendors
  - test laboratories

- Apkudo LLC
- AT&T
- China Academy for Telecommunications Research (China)
- Cisco Systems, Inc.
- DxO Labs (France)
- Huawei Device Company (China)
- Image Engineering Co. GmbH KG (Germany)
- Imatest LLC
- Intel Corporation
- LG Electronics (Korea)
- Microsoft
- NVidia Corporation
- T-Mobile US

All others are USA members

# IEEE P1858 - Standard for Camera Phone Image Quality (CPIQ)

https://standards.ieee.org/develop/project/1858.html

- **IEEE P1858 - Standard for Camera Phone Image Quality (CPIQ)** specifies methods and metrics for measuring and testing camera phone image quality to ensure consistency of image quality. It defines a standardized suite of objective and subjective test methods for measuring camera phone image quality attributes, and it specifies tools and test methods to facilitate standards-based communication and comparison among carriers, handset manufacturers, and component vendors regarding camera phone image quality.
- **The IEEE CPIQ Conformity Assessment Steering Committee** is being formed to create an industry supported consumer rating system based on the forthcoming IEEE P1858 standard, which is intended to address the fundamental characteristics that contribute to image quality.

# CPIQ Consumer Rating System

**Level One:** Single rating that is weighted or linear combination of ratings one level below

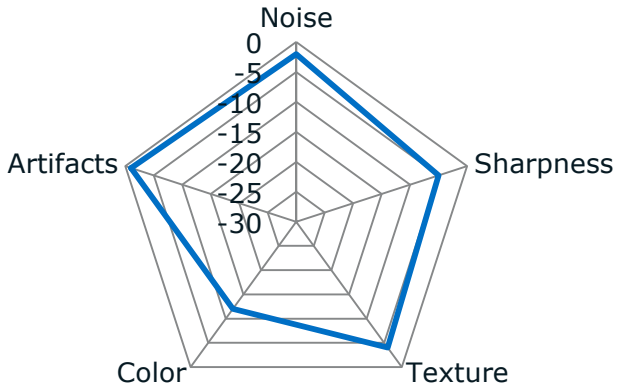
**Use case**

*Camera Rating = f(Outdoor, Indoor, Lowlight)*

**Level Two:** Three ratings for three use-cases: Outdoor, Indoor, Low-Light (defined by light level, e.g. 1000 lux, 100 lux, 10 lux)

**Multivariate formulism**

**Level Three:** Radar plot with key metrics



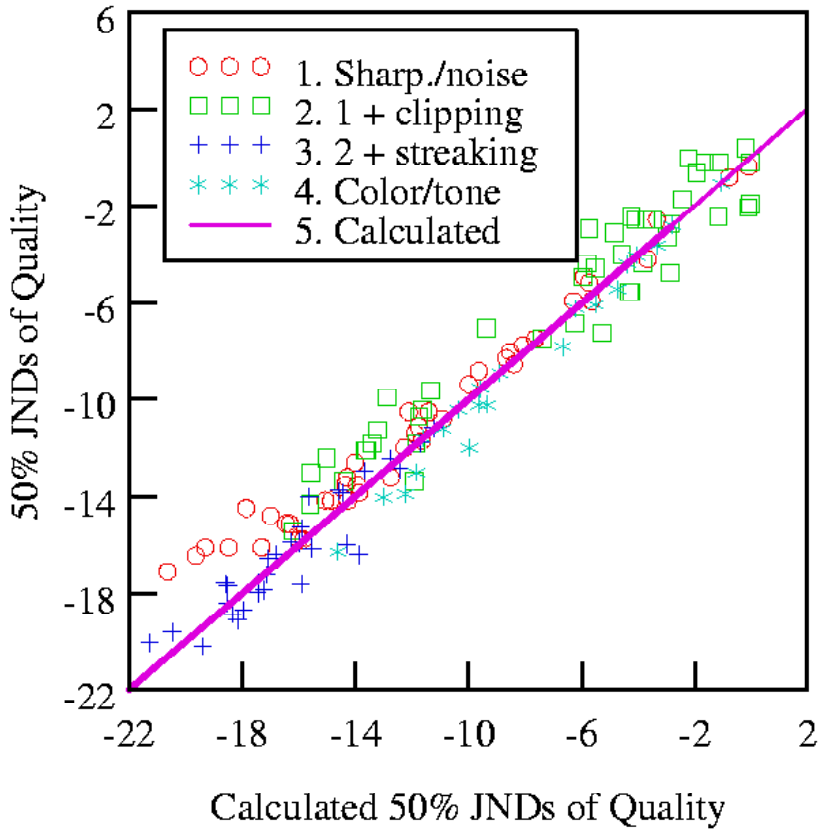
# Level 3 -> Level 2 Conversion

- **Multivariate formulism** (Keelan, 2002) can be used to predict overall quality from individual attributes
- Minkowski metric is used to calculate the overall quality metric from individual metrics

$$\Delta Q_m = -\left( \sum_i \left(-\Delta Q_i\right)^{n_m} \right)^{1/n_m}$$

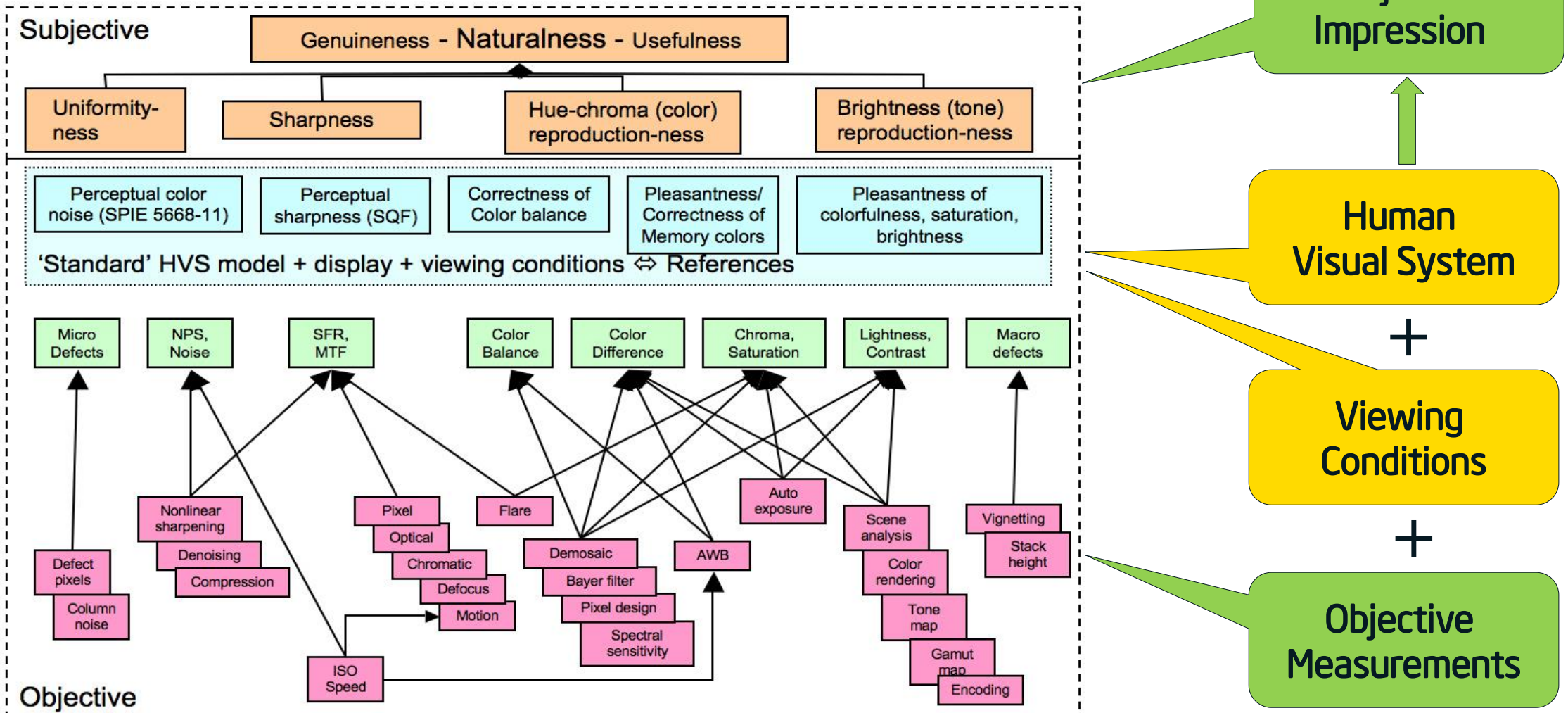
- The Minkowski power is calculated as:

$$n_m = 1 + 2 \cdot \tanh\left( \frac{(-\Delta Q)_{\max}}{16.9} \right)$$




Multivariate formulism was established based on four Kodak studies shown here.

# CPIQ Metrics Consider Human Visual System & Viewing Conditions

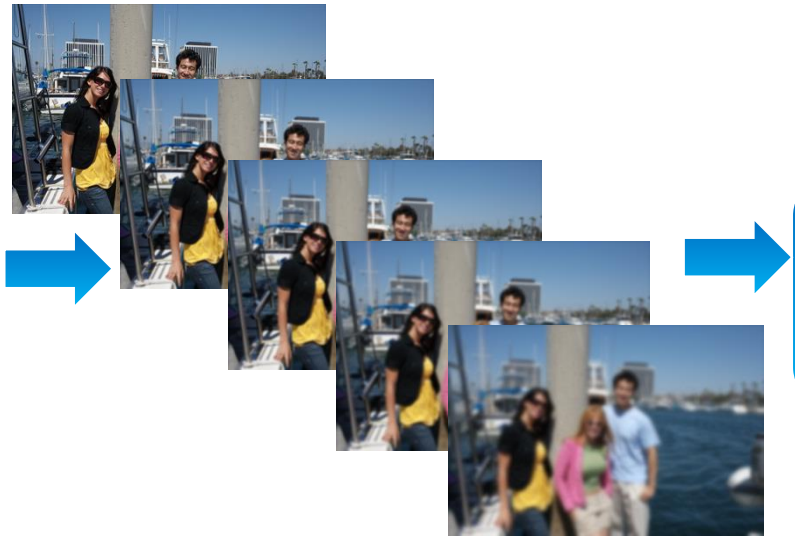



Reference: CPIQ Phase 1 White Paper

# CPIQ Metrics are Linked to Subjective Image Evaluations

Test Image for Subjective Evaluation

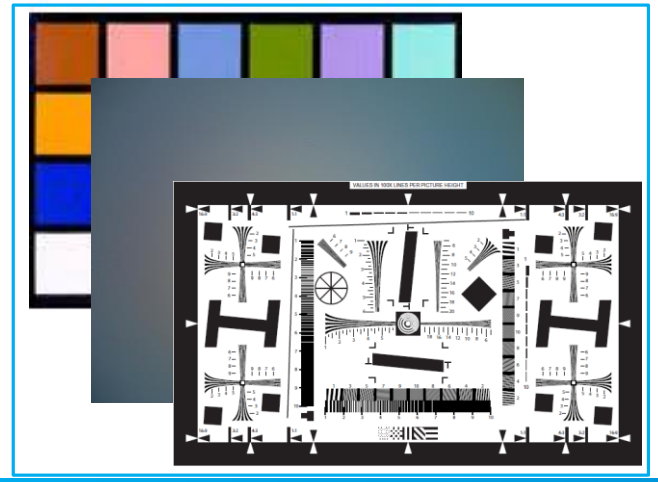
Image Attribute Treatment



Observer Rating using **Softcopy Oruler**

Subjective measurement – JND loss

IQ Degradation



**Objective Metric**

# CPIQ Metrics

| CPIQ Metrics | Symbols | Artifactual/ Preferential |
|---|---|---|
| Spatial frequency response | SFR | Artifactual |
| Lateral chromatic displacement* | LCD | Artifactual |
| Chroma level | | Preferential |
| Color uniformity | | Artifactual |
| Local geometric distortion* | LGD | Artifactual |
| Visual noise | | Artifactual |
| Texture blur | | Artifactual |

# Spatial Frequency Response (SFR)

Acutance

$$Q = \frac{\int_0^{\nu_c} \mathrm{SFR}(\nu) M(\nu) \mathrm{CSF}(\nu) d\nu}{16.88}$$

SFR metric

$$B = 0.8859 - Q \quad Q \le 0.8859$$
$$B = 0 \quad Q > 0.8859$$

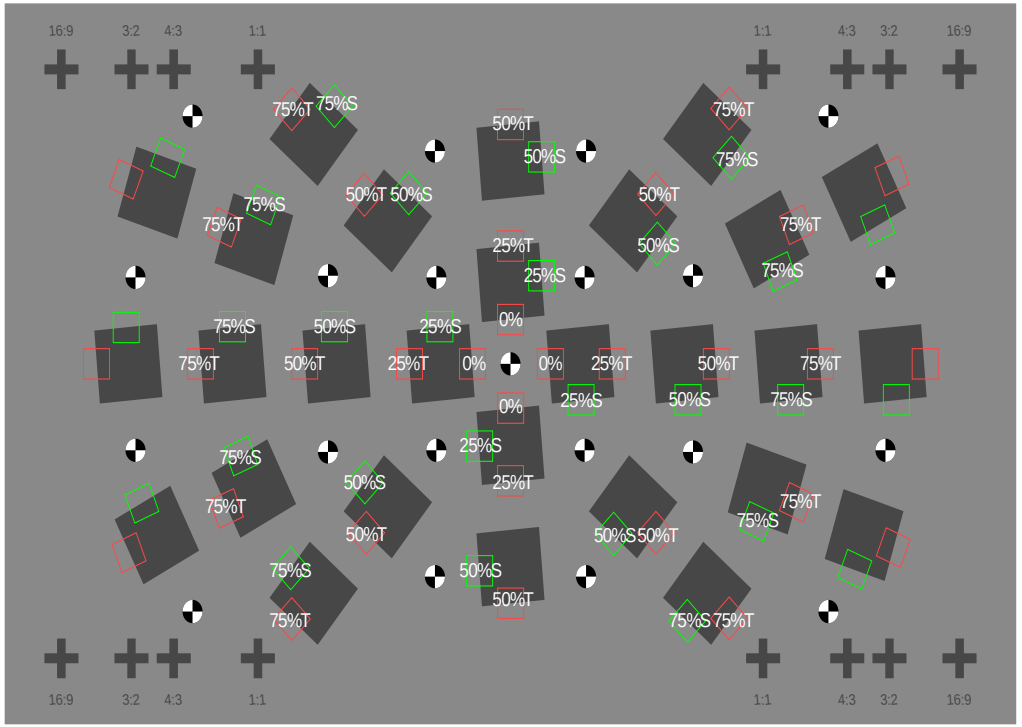
Quality loss

$$\text{JND quality loss} = \frac{3.360 \times 10^{-3} - 2.336B + 164.1B^2 - 191.8B^3 + 16.32B^4}{1.000 - 0.08655B + 0.9680B^2 - 2.306B^3}$$

$$_{\max} - \mathrm{JND}$$

This formula was derived from ISO 20462 Part 3 equations, not from CPIQ subjective studies.

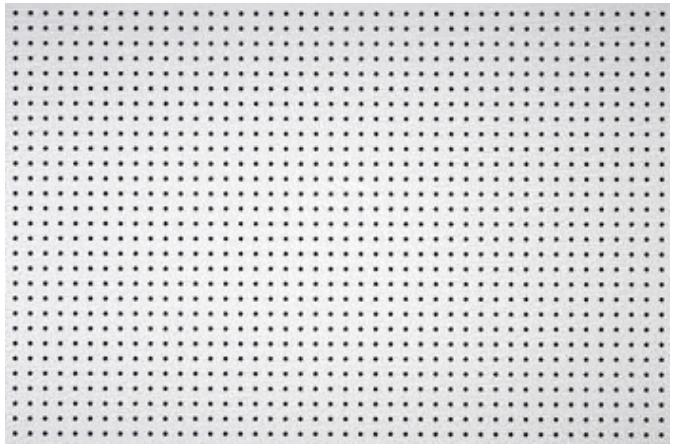
SFR Chart




- ROI: 32x32 pixels
- Low contrast edges
- Automation landmarks
- Framing marks

# Lateral Chromatic Displacement (LCD)

## Dot Chart



boat_people_LCA_pix00.bmp 1253x834

FarmStand1_LCA_pix00.bmp 816x1088

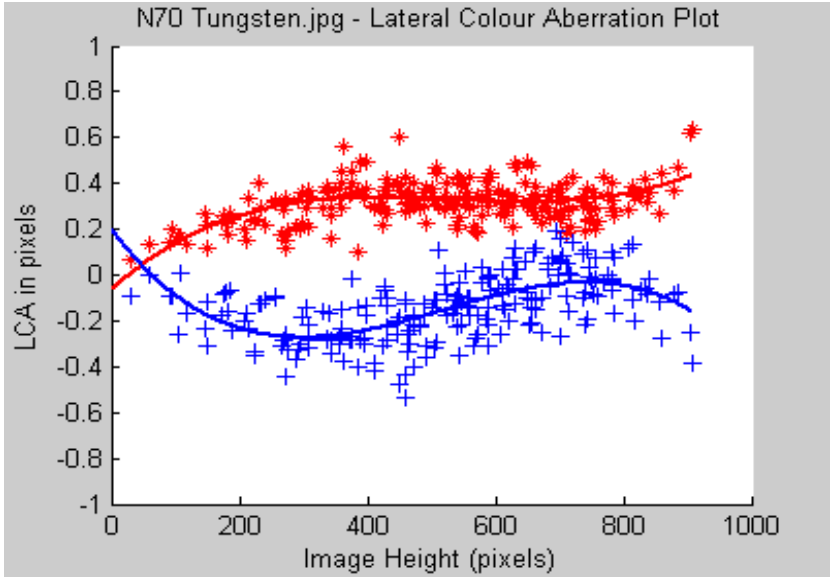
Field_LCA_pix00.bmp 1088x816

GeorgeEastmanHouse_LCA_pix00.bmp 1088x816

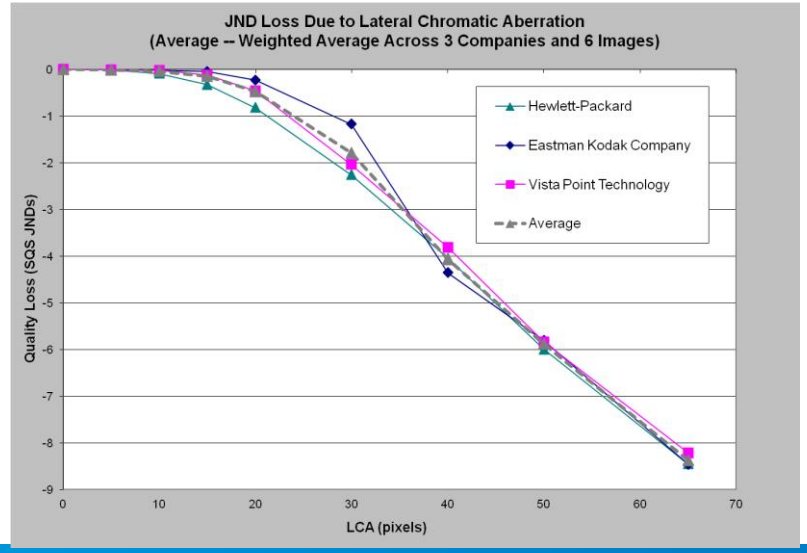
MemorialArtGallery_LCA_pix00.bmp 816x1088

Wedding_LCA_pix00.bmp 816x1088

## LCD Metric




## Quality Loss Function



# Chroma Level

$$C_M = \frac{1}{N}\sum_{i=1}^{N}\sqrt{a_{Mi}^2 + b_{Mi}^2}$$

Chroma

$$C_R = \frac{1}{N}\sum_{i=1}^{N}\sqrt{a_{Ri}^2 + b_{Ri}^2}$$

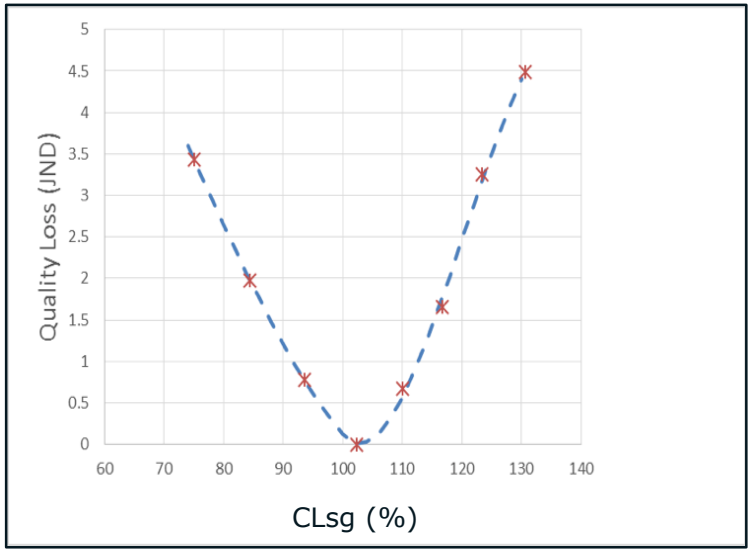
Chroma Level Metric

$$CL_{sg} = \frac{C_M}{C_R} * 100\%$$

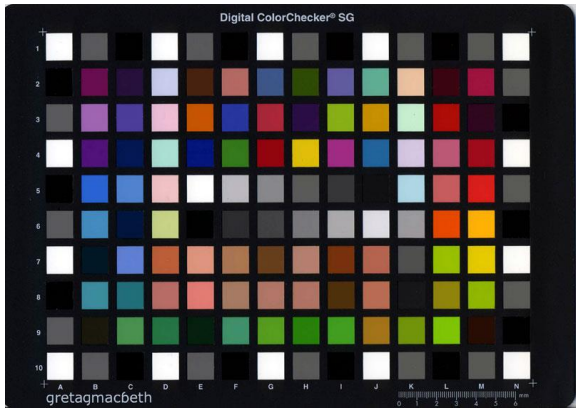
Quality Loss Function

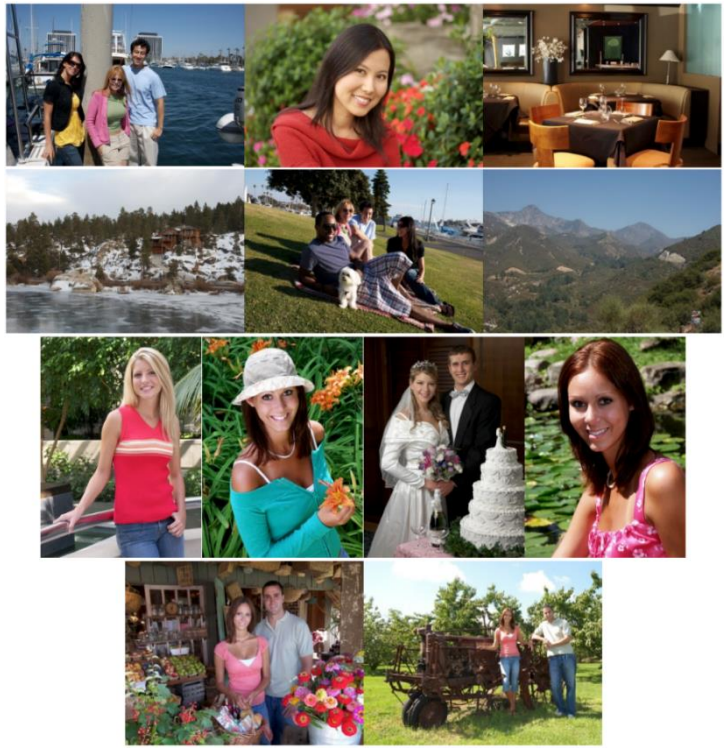
$$QL = k * \left(1 - e^{-\left((a*|CL_{sg}-p)^r\right)}\right)$$

| Constant | CLsg <= 102.4 | CLsg > 102.4 |
|---|---|---|
| p | 102.4 | 102.4 |
| a | 0.0064 | 0.0402 |
| r | 1.357 | 1.978 |
| k | 38.282 | 6.216 |




Digital ColorChecker SG



This is the newest addition to the CPIQ set of metrics.

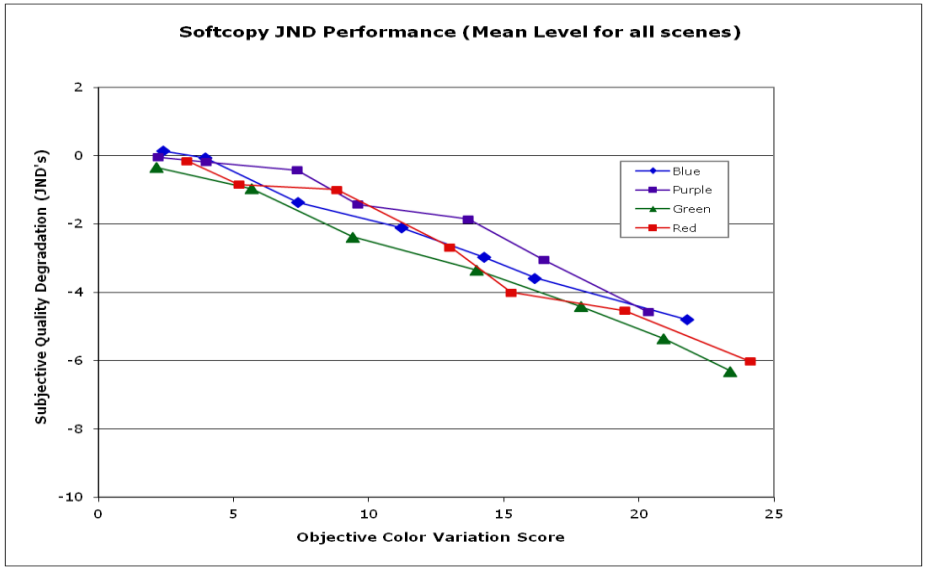
# Color Uniformity

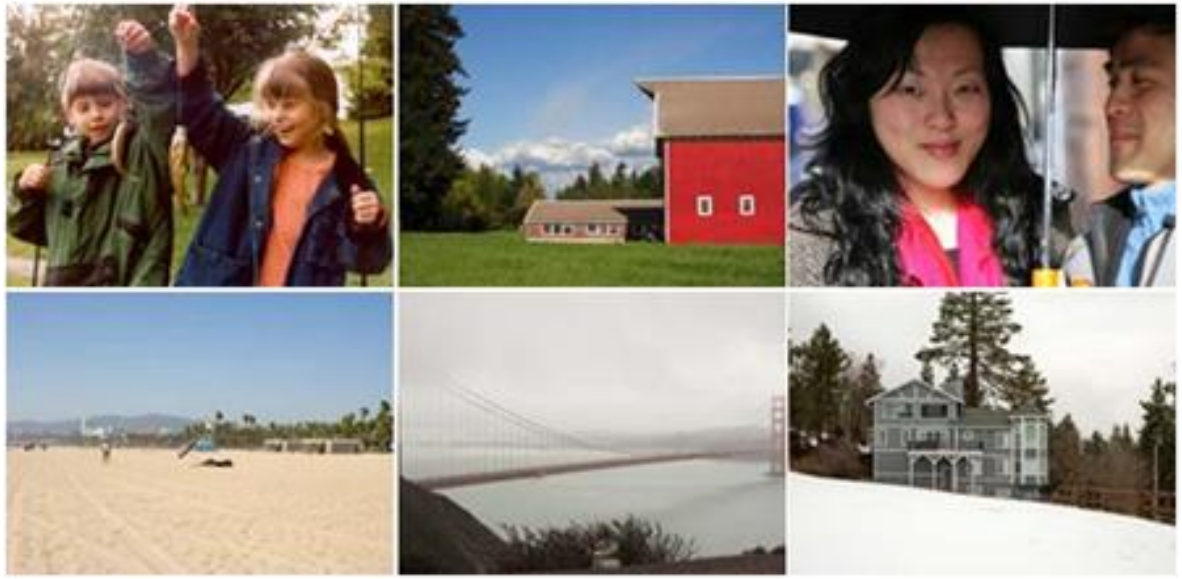
White Board / Diffuser

## Color Uniformity Metric

$$D_c = \max_i D_c(i) \qquad D_c(i) = \sqrt{(a(i) - \bar{a})^2 + \left(b(i) - \bar{b}\right)^2}$$

## Quality Loss Function

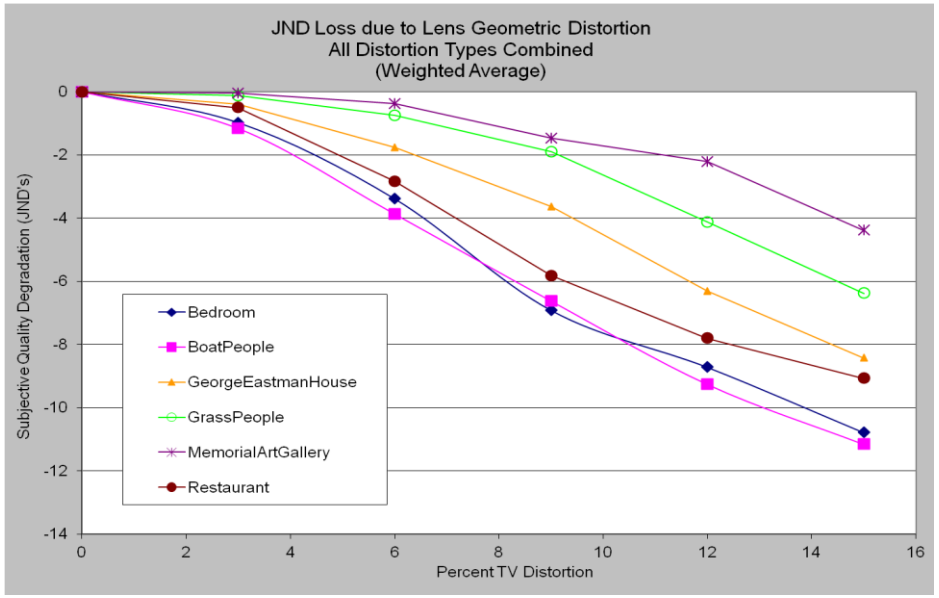


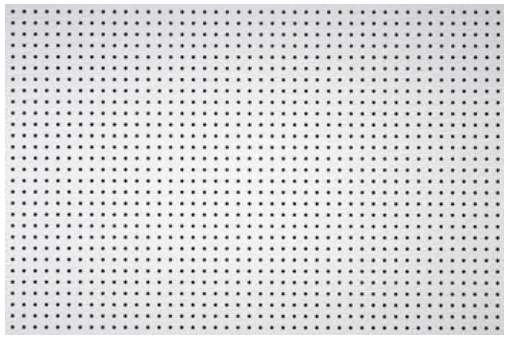
# Local Geometric Distortion (LGD)

LGD Metric
OM = 100.0 * (H’ – H) / H

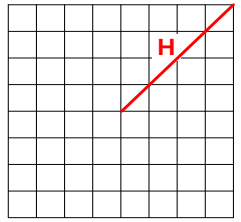
Quality Loss Function



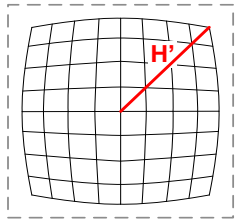

Dot Chart



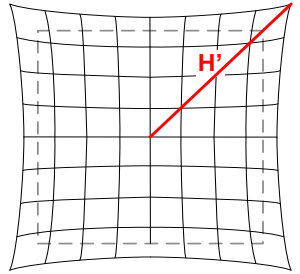
Undistorted Grid




Barrel Distortion
*(Negative)*




Pincushion Distortion
*(Positive)*





bedroom_8bit_fullres_corrLGDLCA_1MP


boat_people_retouch_8bit_2degCCW_vCrop

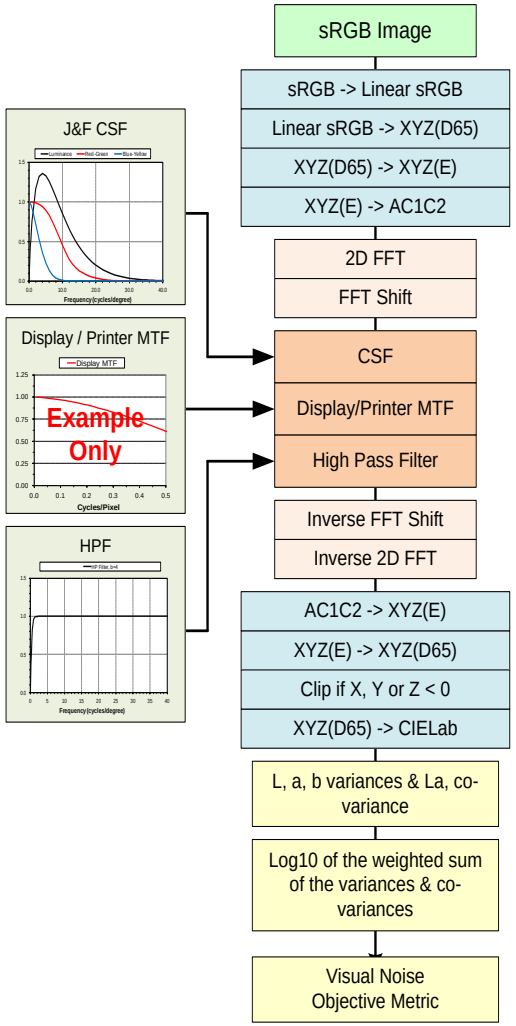

GeorgeEastmanHouse_dxo_1MP


grass_people_retouch_8bit_fullres_corrLGDLCA_crop

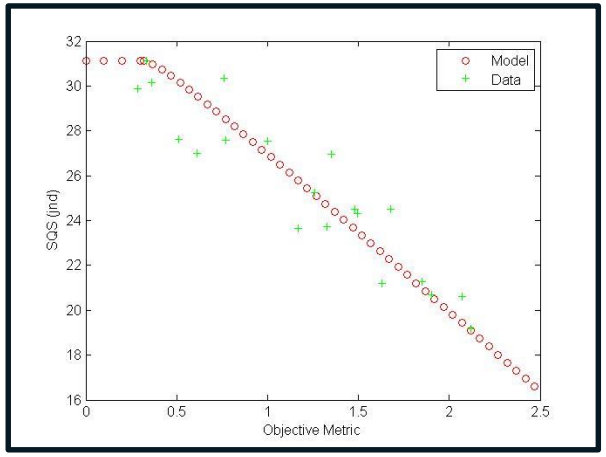

MemorialArtGallery_dxo_1MP

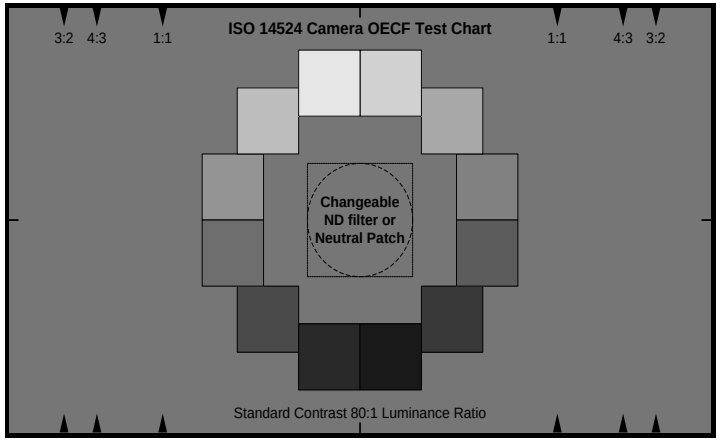

restaurant_retouch_8bit_fullres_corrLGDLCA_1MP

# Visual Noise




## Quality Loss Function



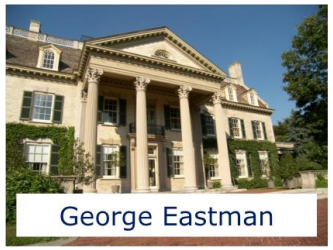




QL = (OM-a)/b - c/b^2 * ln(1 + b*(OM-a)/c)
if OM >= 0.3185
QL = 0
otherwise

a = 0.3185
b = 0.1380
c = 0.0049





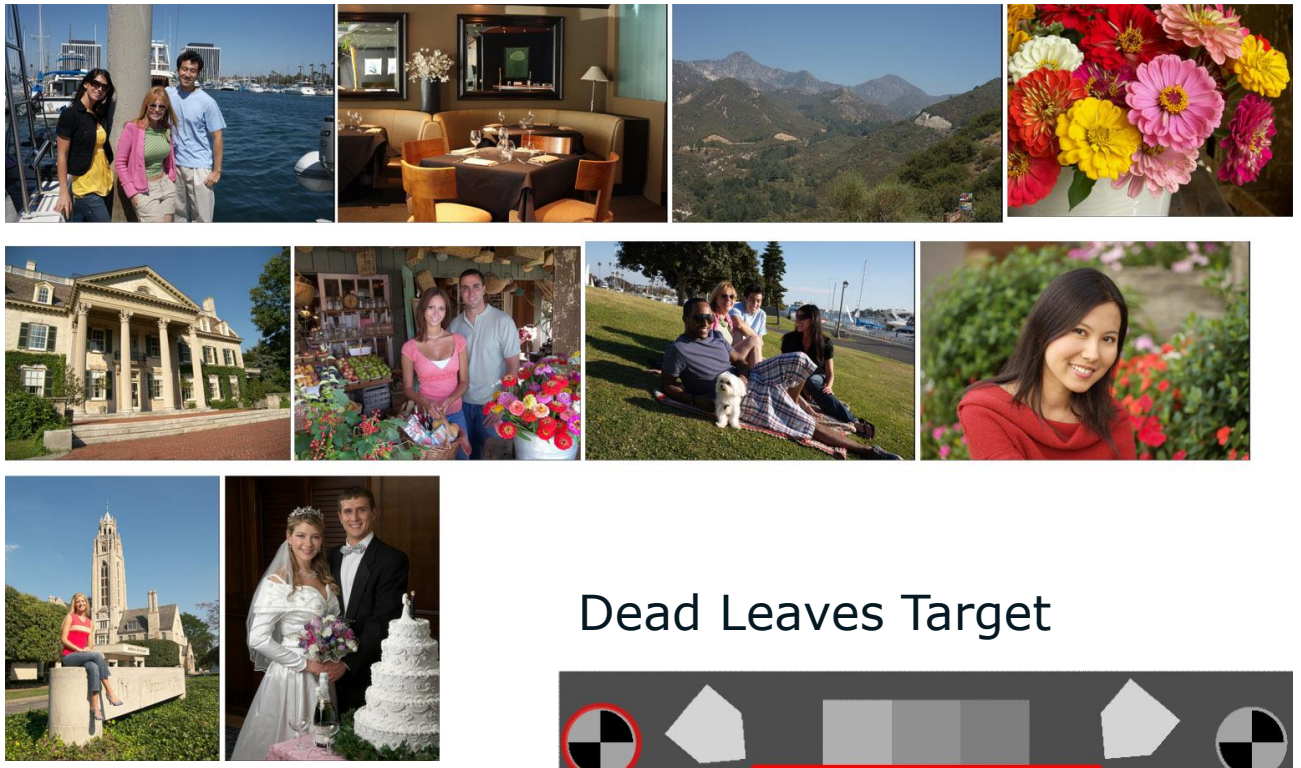




VN objective metric is measured on L* = 50 neutral patch

# Texture Blur

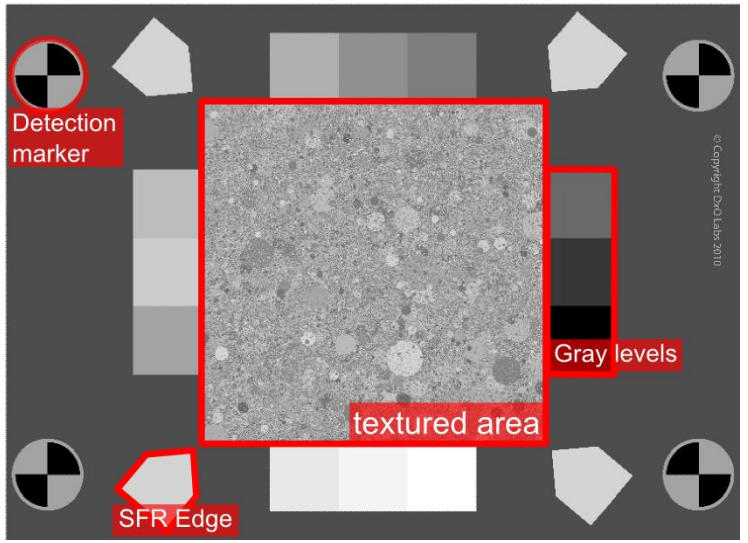
$$MTF = \left( \frac{PSD(image) - PSD(noise)}{PSD(target)} \right)^{1/2}.$$



## Texture Blur Metric

$$\text{Texture Acutance} = \frac{\int_0^{v_s} MTF_L(v) \cdot M(v) \cdot CSF_L(v) dv}{16.88}$$

## Dead Leaves Target



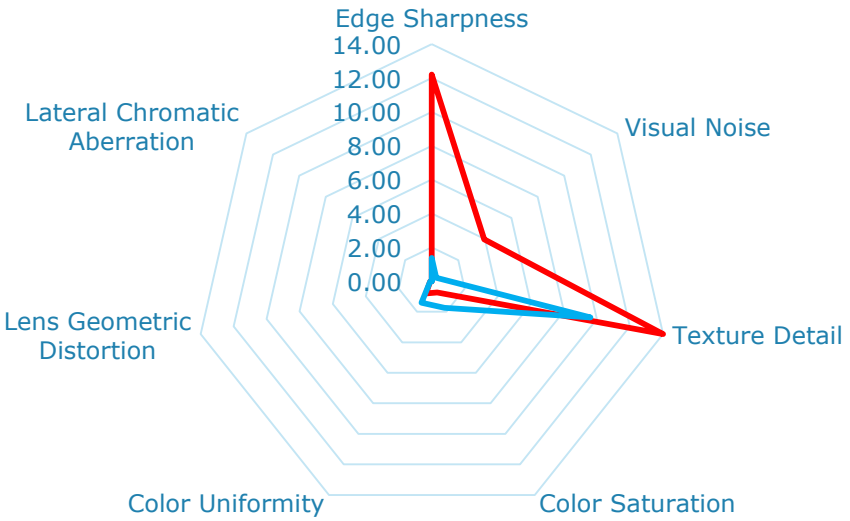

## Quality Loss Function

$$\text{JND} = (21.5 \times \text{Texture Acutance}) + 11.7 \qquad \text{Texture Acutance} \leq 0.95 \qquad (32)$$

$$\text{JND} = 32.1 \qquad \text{Texture Acutance} > 0.95$$

# Example CPIQ Test Results (10 lux)

| CPIQ Metrics | Device1 (JND) | Device2 (JND) |
|---|---|---|
| Edge Sharpness | 12.20 | 1.37 |
| Visual Noise | 3.97 | 0.33 |
| Texture Detail | 14.00 | 9.60 |
| Color Saturation | 0.73 | 1.74 |
| Color Uniformity | 0.80 | 1.40 |
| Local Geometric Distortion | 0.10 | 0.10 |
| Lateral Chromatic Displacement | 0.00 | 0.00 |
| Overall quality loss | 17.86 | 9.93 |



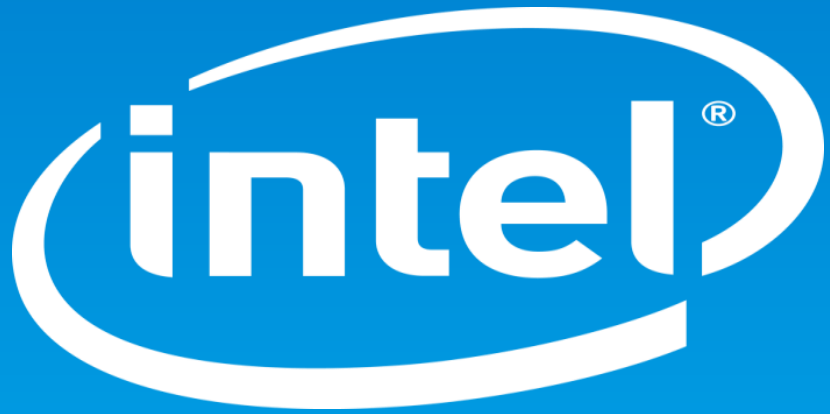

| | | | | | | |
|---|---|---|---|---|---|---|
| Standard Quality Scale (JND) | 32 | | 24 | 16 | 8 | 0 |
| Quality Loss Scale (JND) | **0** | | **8** | **16** | **24** | **32** |
| Quality Category Scale | **Excellent** | **Very Good** | | **Good** | **Fair** | **Poor** | **Not Worth Keeping** |

# CPIQ and ISO Alignment

| CPIQ Metric | ISO Counterpart | Status |
|---|---|---|
| Spatial frequency response | | |
| Lateral chromatic displacement | ISO 19084 – Chromatic displacement | Submitted for publication |
| Chroma level | | |
| Color uniformity | ISO 17957:2015 - Shading measurements | Published |
| Local geometric distortion | ISO 17850 – Geometric distortion measurements | Submitted for publication |
| Visual noise | ISO 15739 – Noise measurements Annex B Visual noise | Ad hoc group, work in progress |
| Texture blur | | |

# CPIQ Metrics Under Development

- Color and tone
  - AWB metric: aim and quality falloff, Phase one results will be reported in Oct 2015
  - AE metric: two proposals will be discussed in Oct 2015
- Visual noise
  - Develop metrics to measure visual noise including chroma noise and effect of noise reduction
- Video quality
  - Dynamic image (with motion blur): SNR and Spatial Resolution
  - Video Stabilization
  - Image Lag
  - Convergence rate for 3A algorithm
  - Frame rate consistency/jitter


intel