Reducing the cross-lab variations of image quality metrics

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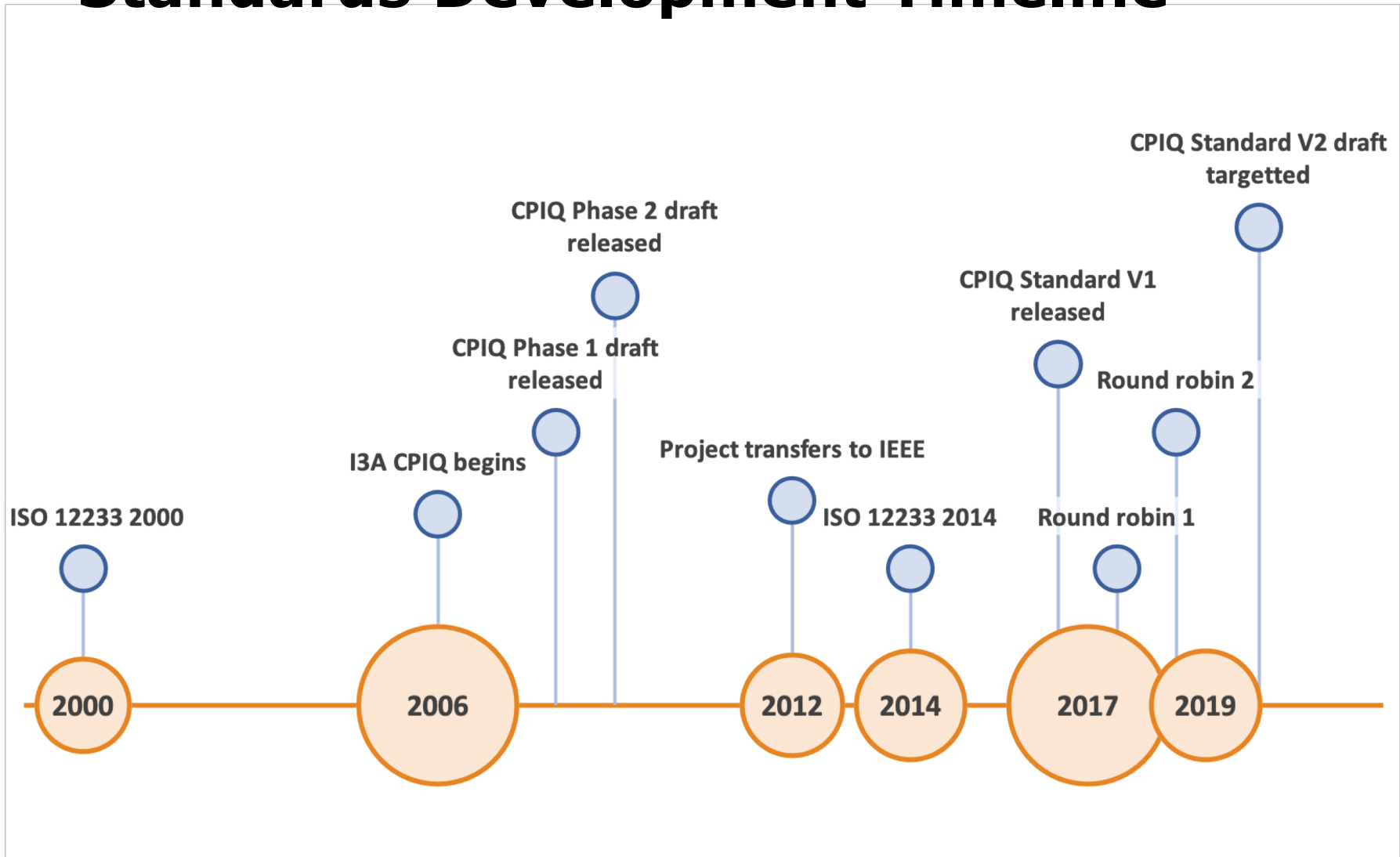**Vickrant Zunjarrao, Microsoft Corp. <vizunj@microsoft.com>**

IEEE 1858 working group vice chair

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IEEE CASC working group vice chair

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Standards Development Timeline

Reducing the cross-lab variations of image quality metrics

Camera Phone Image Quality (CPIQ)

Objective, perceptual-based image quality metrics

Scored in Just Noticeable Differences (JNDs)

7 metrics in 1858-2016 standard

Drivers of variation:

SFR
TB — Texture Blur
VN — Visual Noise

Chart contrast & spatial contents

Scene luminance & metering mode

CL — Chroma Level
CU — Color Uniformity

Near infrared in light source

LGD — Lateral Geometric Distortion
LCA — Lateral Chromatic Aberration
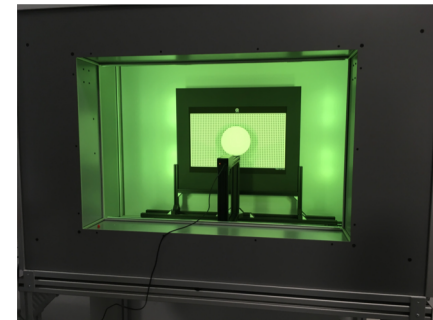
High quality / low variation

Where variation comes from

Mobile devices are "black box" cameras with dynamic image signal processors (ISPs):

- Nonlinear spatial processing
- Automatic Exposure
- Automatic White Balance
- Autofocus

Labs have varying:

- Light sources (CCT / spectra)
- Test charts (reflectance / frequency / quality)
- Distances
- Human-constructed labs
- Human-executed capture procedures
- Human-sorted data sets
- Human-implemented algorithms

Round Robin Studies

Round Robin 1	Round Robin 2
June-2016 to July-2017	Oct-2017 to Dec-2018
iPhone 4 iPhone 5C iPhone 5S iPhone 6S Plus HTC One M8 LG G2 Nexus 6P Sony Experia Z5 Galaxy S7 Edge	iPhone 8 Plus iPhone 5S iPhone 6S Plus LG G2 Nokia 1020 Samsung S7 Edge Huawei P10 Xiaomi Mi6 OPPO R11 Google Pixel Microsoft Surface Pro (Front & Rear)
6 Labs	5 Labs
28 images / device	105 Images / device
1512 images	5775 images

Standard Lighting Conditions

Illuminant	CCT	Lux	Notes
Outdoor D55 based on ISO 7589	5500K +- 700K	1000 +- 100	Tunable LED or filtered halogen. - Must include NIR for color uniformity test.
Indoor TL84 Fluorescent	4100K +- 300K	100 +- 10	Must be fluorescent.
Low Light Tungsten based on ISO 7589	3050K +- 300K	25 +- 2.5	Tungsten or tunable LED - Must include NIR for color uniformity test

SFR - Missed focus

Especially in low light, an autofocus failure can ruin SFR
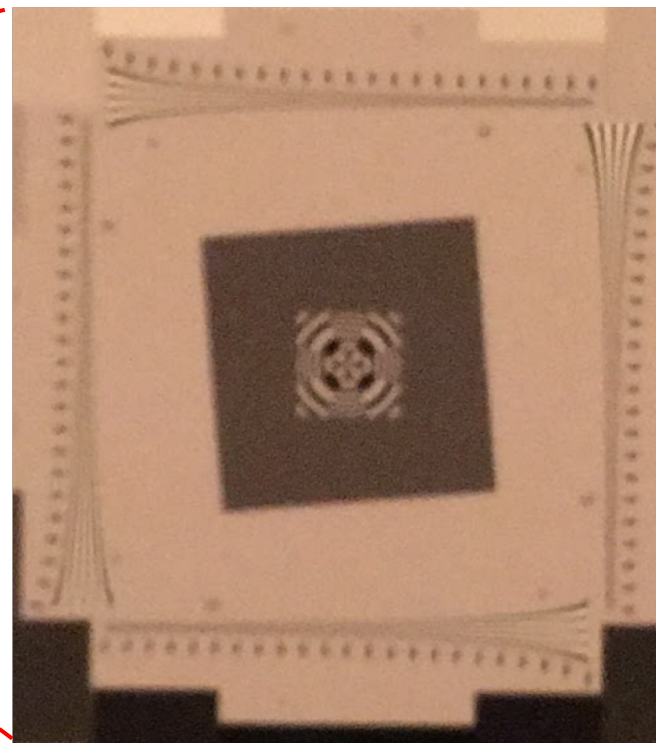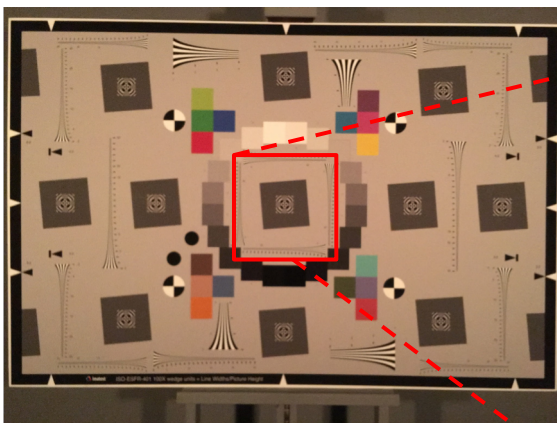
Corrective action:

Ensure adequate chart quality by using large
4x sized ISO charts (1225 x 800mm)

Select best of 10 exposures

Add autofocus repeatability score to next
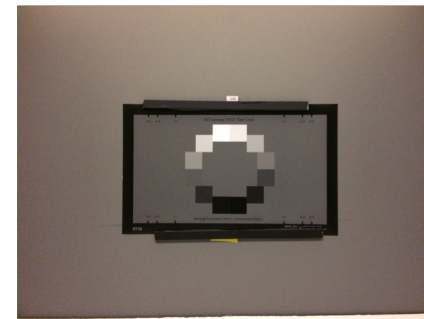standard

SFR: 27.24 JND of Quality Loss

SFR Variation

Outdoor SFR · Indoor SFR · Lowlight SFR

Quality Loss JND

Devices (all three charts): Galaxy S7 edge, pixel, Oppo R11, Nokia 1020, LG G2, iPhone5, SurfacePro4, HuaweiP10, iPhone8+, iPhne6S+
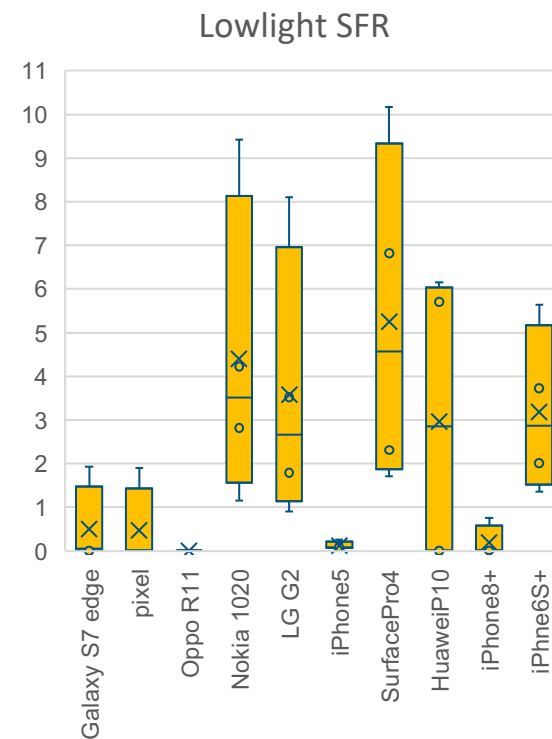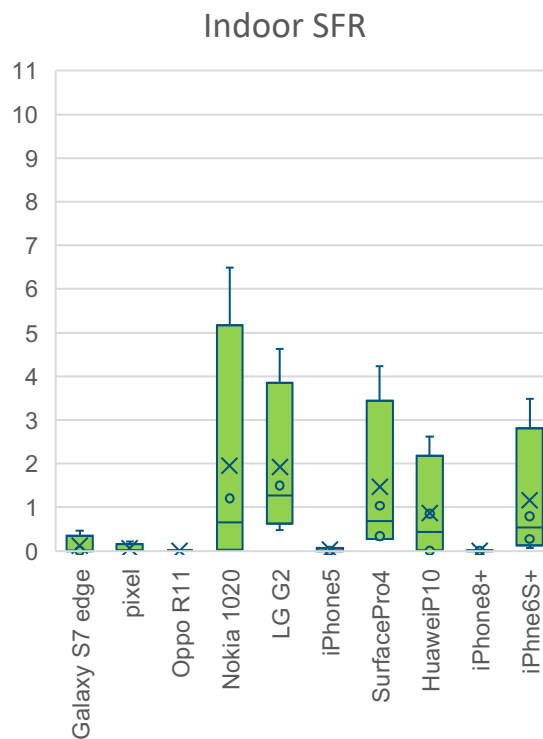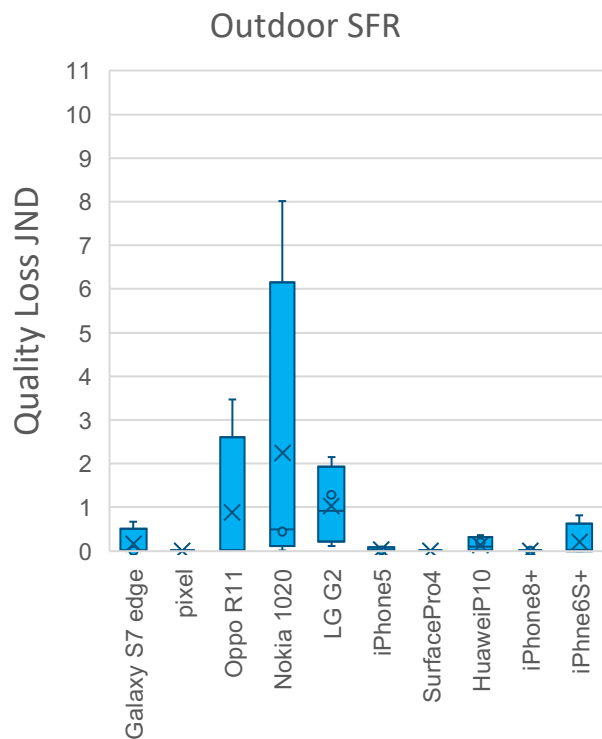
Exposure is Scene-Dependent
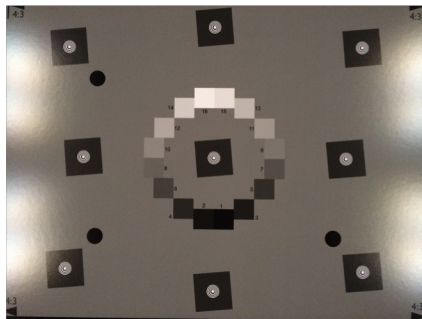
6.22 JND QL   **ISO 400**
Specular corruption

6.8 JND QL   **ISO 500**

7.90 JND QL   **ISO 640**
18% grey background

Reflectance determines luminance
Luminance determines ISO speed
Impacts visual noise & texture blur

Corrective action:

Conform to ISO standard framing
Align lab target reflectance

Visual Noise Quality Loss

Chart: JND vs ISO Speed

- 6.22
- 6.8
- 7.9

Y-axis: JND (5 to 8.5)
X-axis: ISO Speed (350 to 650)

Visual Noise Variation
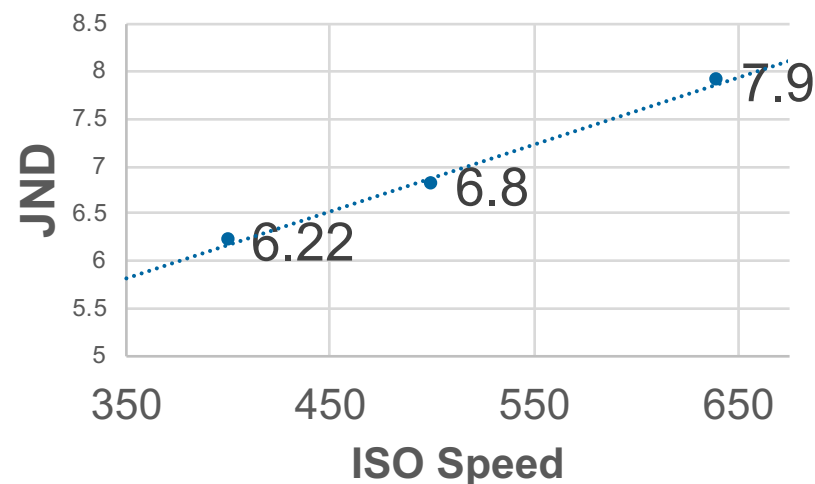
Outdoor Visual Noise (VN) — Indoor Visual Noise (VN) — Lowlight Visual Noise (VN)
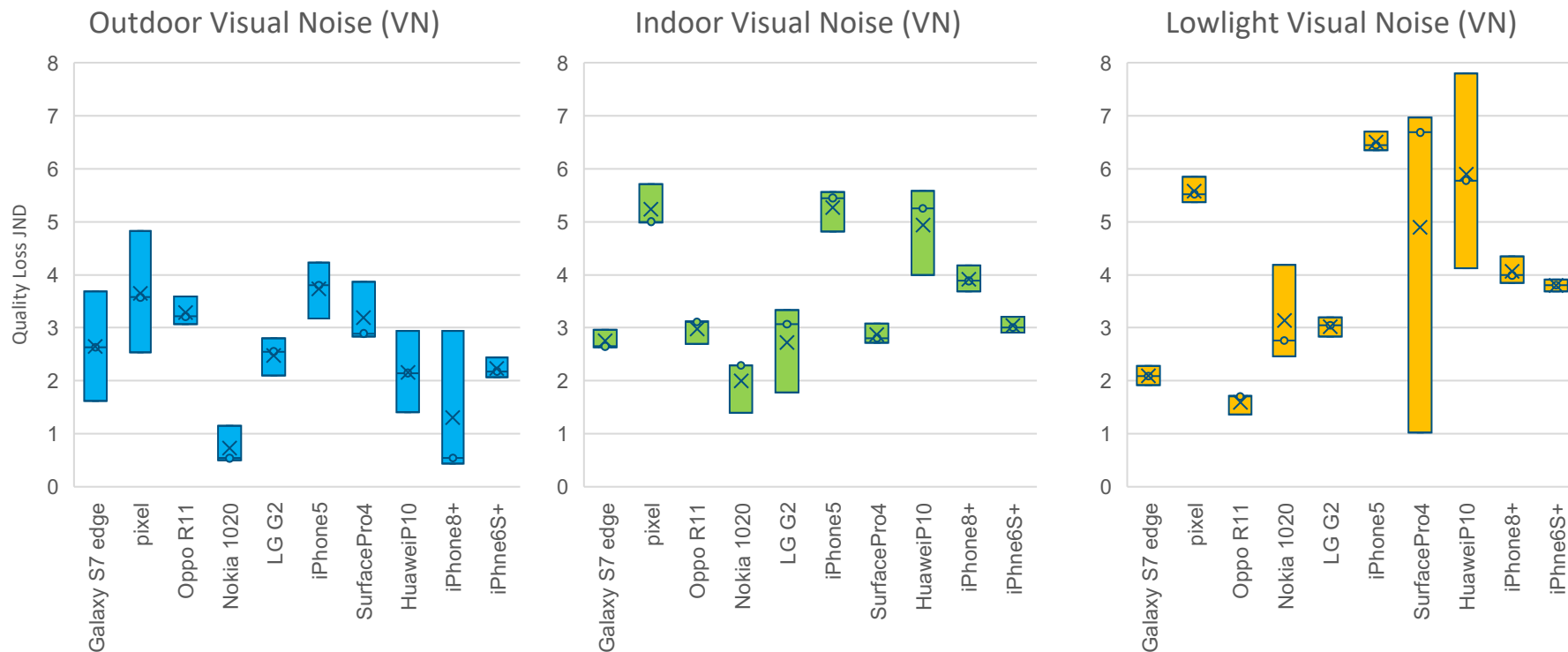
Texture Chart Differences
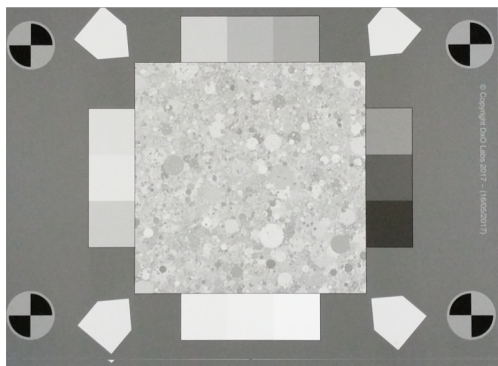
DxOmark Dead Leaves

B&W Imatest Spilled Coins
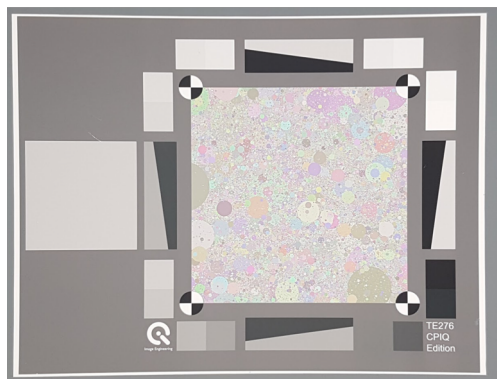
Color IE TE276 CPIQ Edition
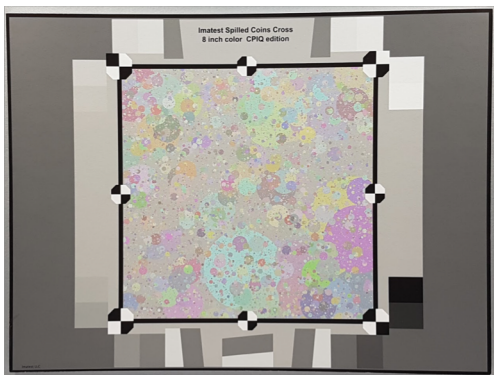
Color Imatest Spilled Coins CPIQ Edition

Different charts have spatial frequency distribution disparities in both luma and chroma

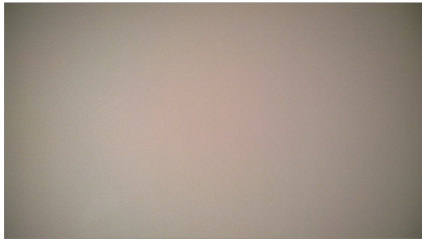Variation was compounded by reflectance and exposure differences
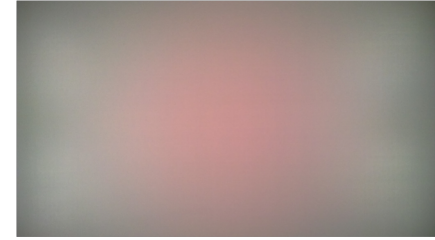
Need to control chart frequency distribution

Texture Variation

Outdoor Texture Blur (TB)

Indoor Texture Blur (TB)

Lowlight Texture Blur (TB)
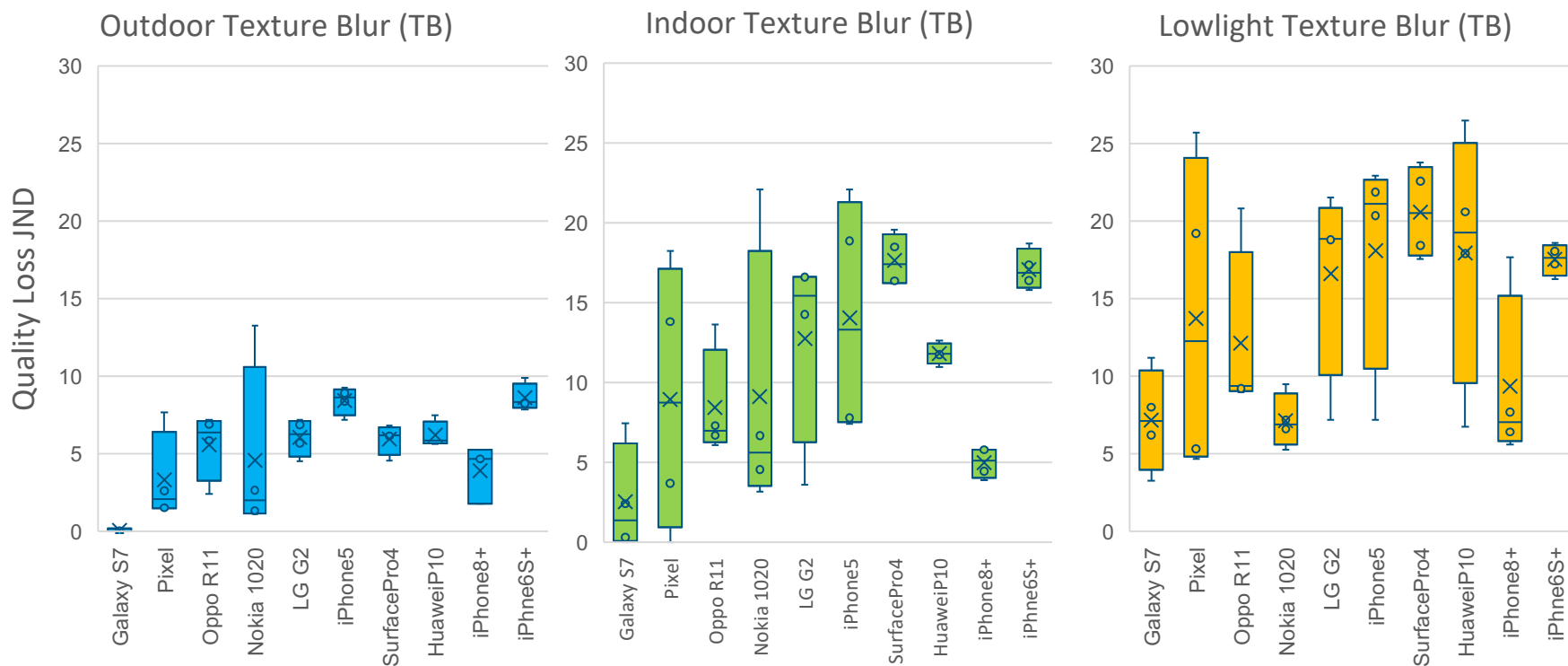
Color Uniformity

Worst device, Low Light (Tungsten ~25 lux)

Lab A: 1.21 JND QL

Lab B: 1.17 JND QL

Lab C: **9.72 JND QL**
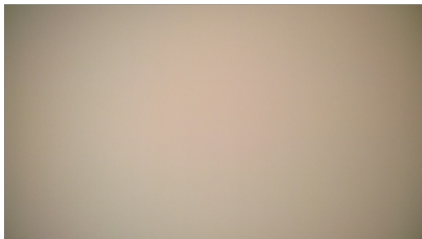
Lab D: 1.35 JND QL
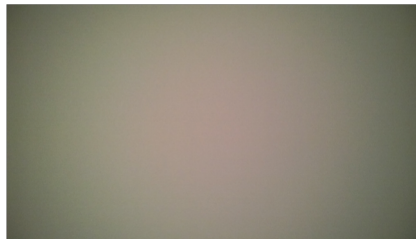
Lab E: 2.43 JND QL
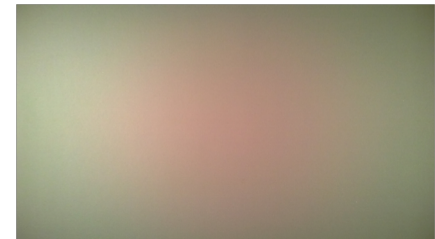
Lab G: **4.93 JND QL**

Strict tolerance on light source color uniformity required
Infrared content is a concern
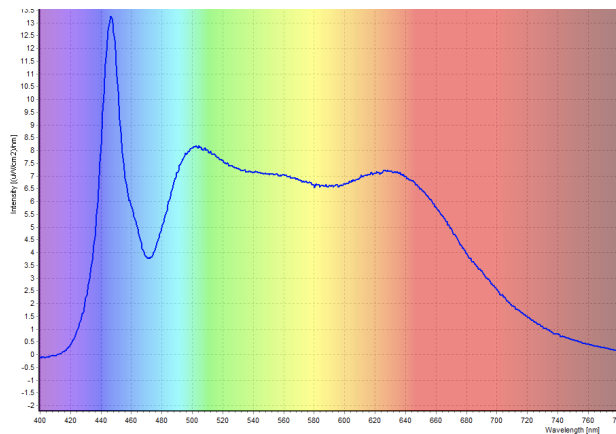
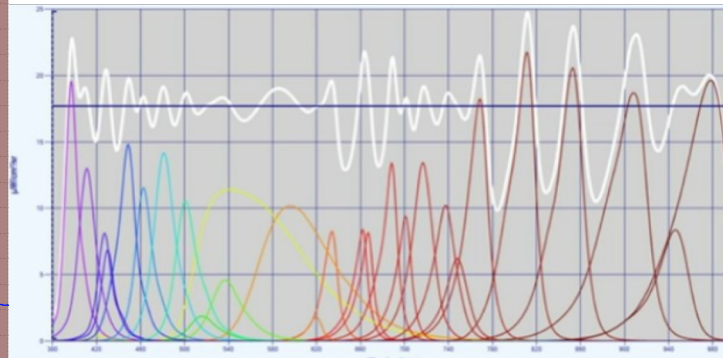# "Daylight" sources for color uniformity

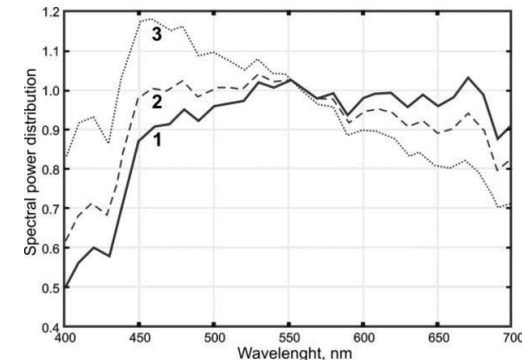

ITI LED Lightbox

Gamma Scientific RS-7

Sol

Phosphor based LED with 5100K CCT
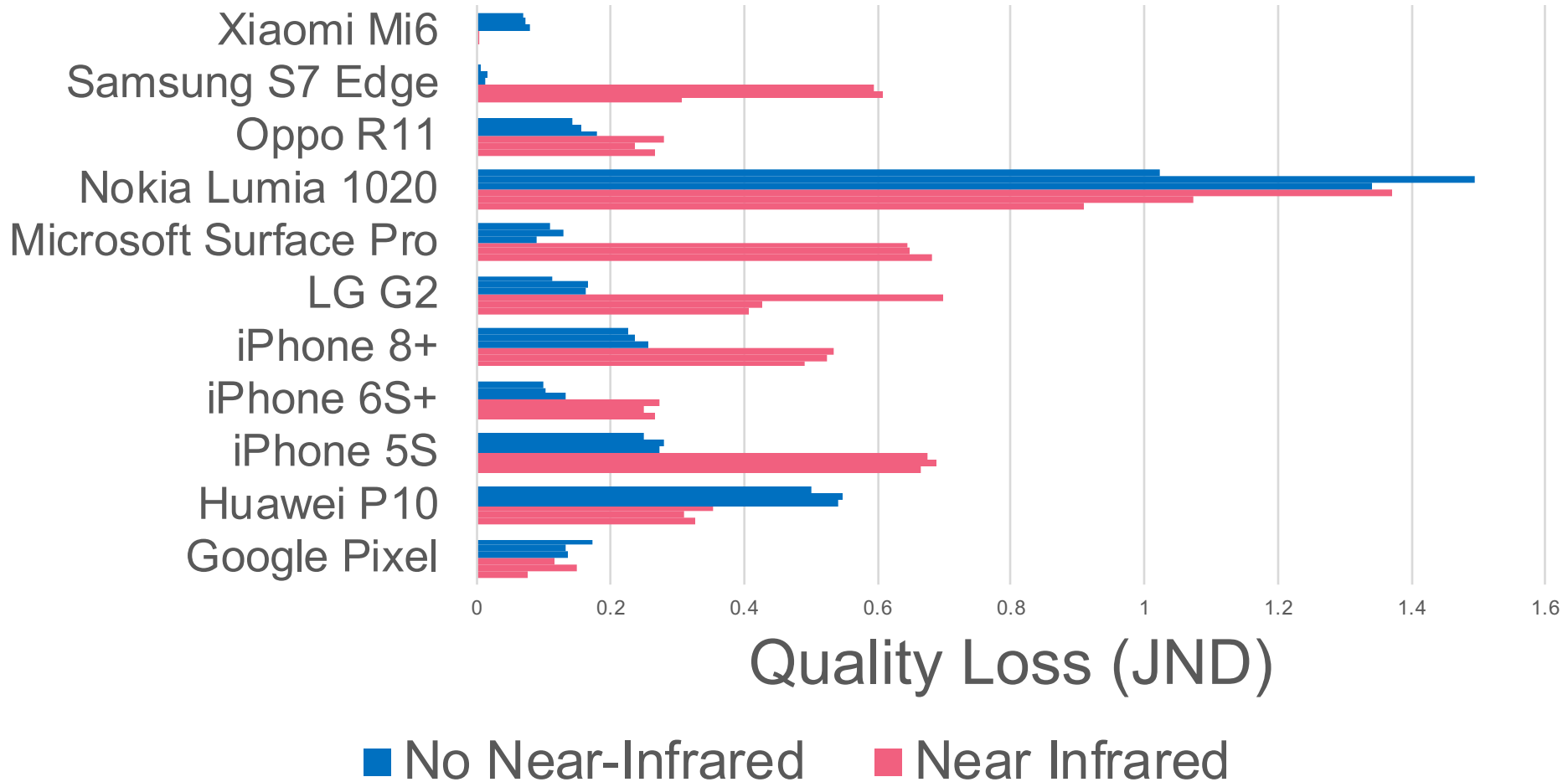drops off around 730nm

32 channel tunable LED
simulating up to 1000nm

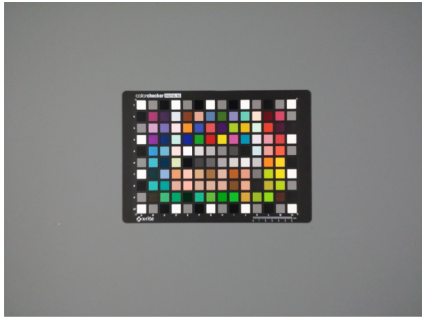Actual Daylight
1- d50 2-d55 3-d65
(source: Dmitry Tarasov)
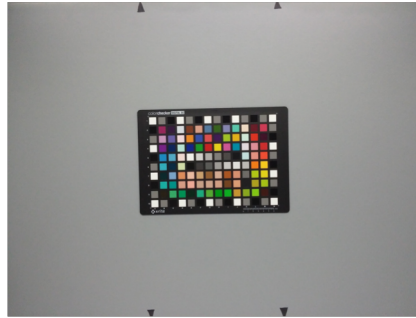
Effect of near infrared on color uniformity

Up to 0.6 JND's of color nonuniformity added by including NIR
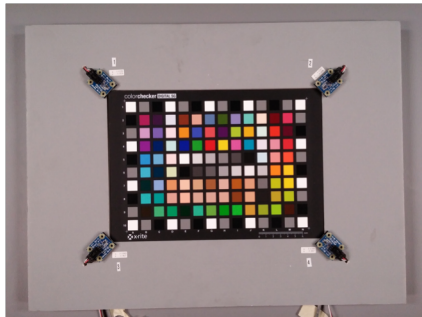
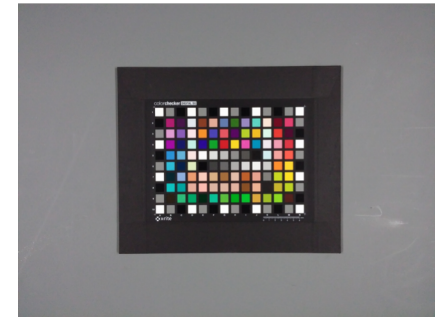# Chroma Level

0.38 JND QL

0.65 JND QL

0.41 JND QL

0.04 JND QL

Lab F: 0.45 JND QL

Lab F: 0.00 JND QL
(Spot meter)

Minimize 'non-chart' and 'non-background' regions

Do not touch the screen to trigger spot metering

IEEE CPIQ Test plan document

- Improved test procedure document available

Published

Links to purchase available for purchase at:

http://bit.ly/labvariation

Summary

Black box cameras vary dramatically based on environment and operator interactions

Current standards alone are not strict enough to get alignment between heterogeneous test labs

Detailed procedures can help make results independently reproducible

Documents from IEEE available for purchase at: **http://bit.ly/labvariation**

Future Work

Publish complete image set

Further analyze the collected images, determine the absolute root causes of the variation

Further tighten testing procedures

Align with ISO 12233 reflectance, and ISO 19567 texture TS chart definition

Correct improper lab setups

Use reference devices to audit labs

Apply Grubbs' test to identify outliers and establish acceptability for a certified lab

Publish device results

CPIQ V2 New Metrics:

Auto Exposure

Autofocus Repeatability

SFR scored across field

Video
- Jitter
- Motion Blur + Texture Loss
- AE Convergence
- AWB Convergence

Documents from IEEE available for purchase at: **http://bit.ly/labvariation**