

# Color Uniformity

Methodology described by:

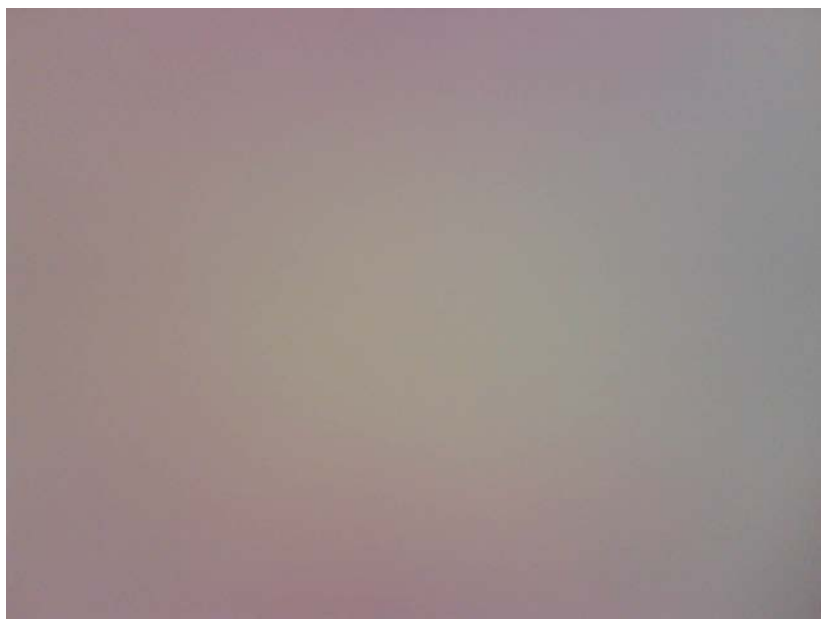
Larry Scarff, Vista Point Technologies

# Color Uniformity Analysis: Purpose and Goal

- **Objective:** *Develop a quantitative metric for the measurement of color uniformity throughout the full field of individual images, which can later be correlated with subjective observations.*
- **Subjective:** *Develop and conduct a consumer-based evaluation of the color non-uniformity in scenes, and deliver a result that characterizes and quantifies the visual detectability for various amounts of color error.*

# Step 1: Examine System Characteristics

- Collected nearly 250 examples of varying uniform fields from actual cell-phone camera modules
- Shown below are two cases with common non-uniformities

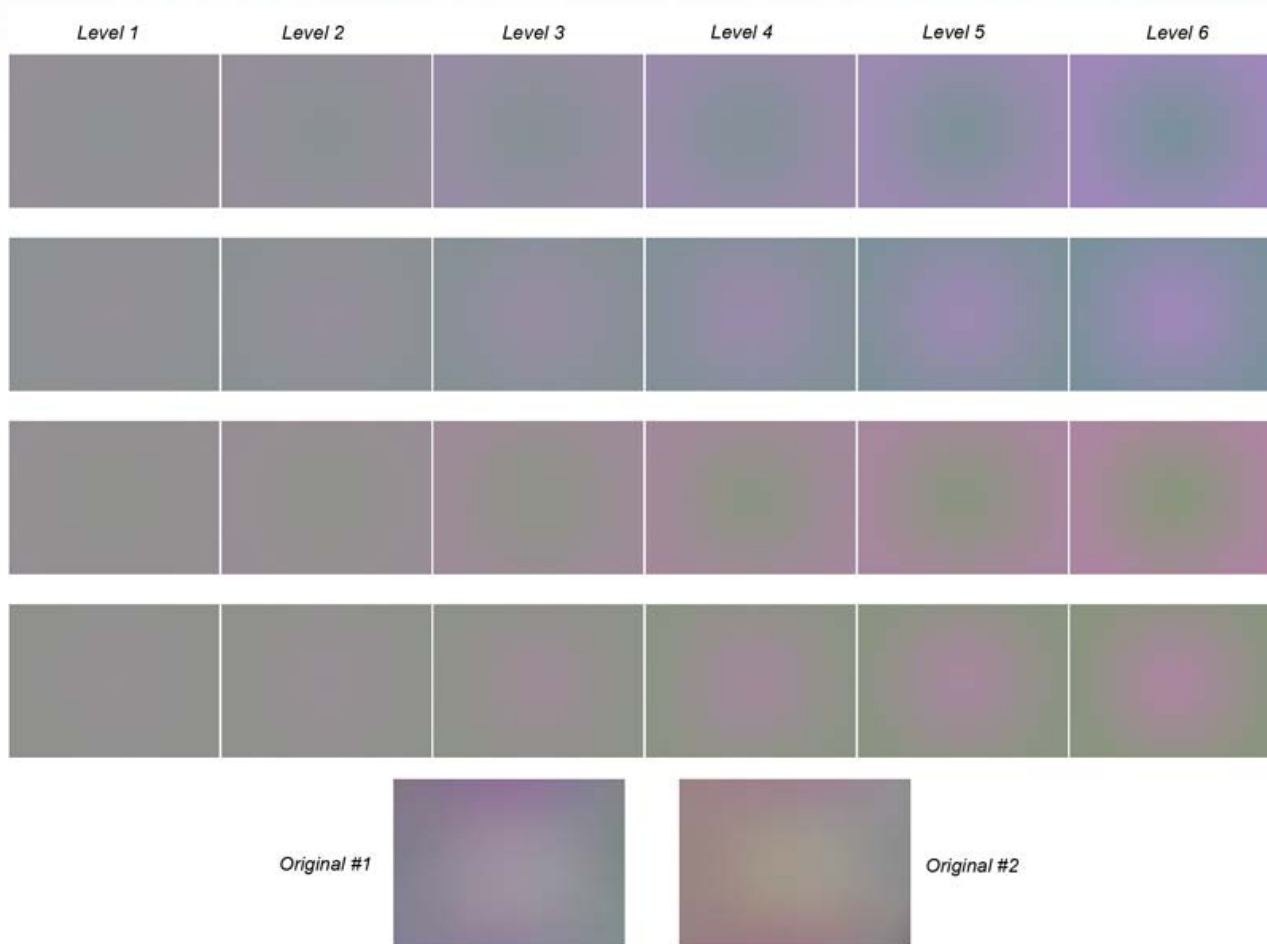


Green/Red variation



Purple/Blue variation

## Step 2: Simulate the artifact



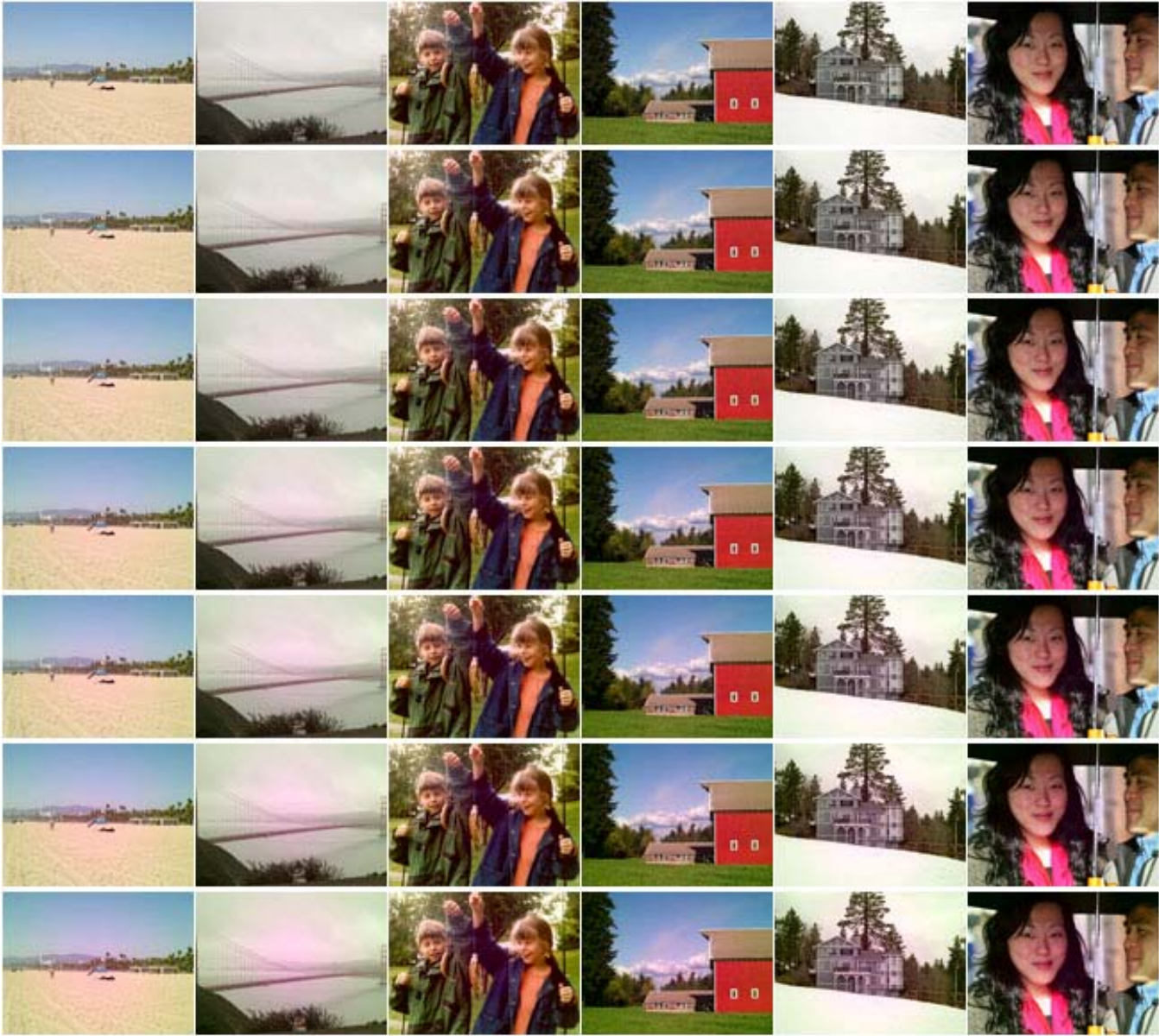
## **Step 3: Apply candidate metrics and implement subjective evaluation**

- Prepare simulated images: 2 color pairs, 7 levels, swap center and edge colors = 28 images
- COmpute color non-uniformity using proposed objective approaches
- Imbed non-uniform test samples within six scenes; three common subjects and three that would be sensitive to color variation
- Independently perform subjective evaluation
- Correlate subjective results with candidate objective metrics and select appropriate algorithm

# Image Test Scenes



# Red Center



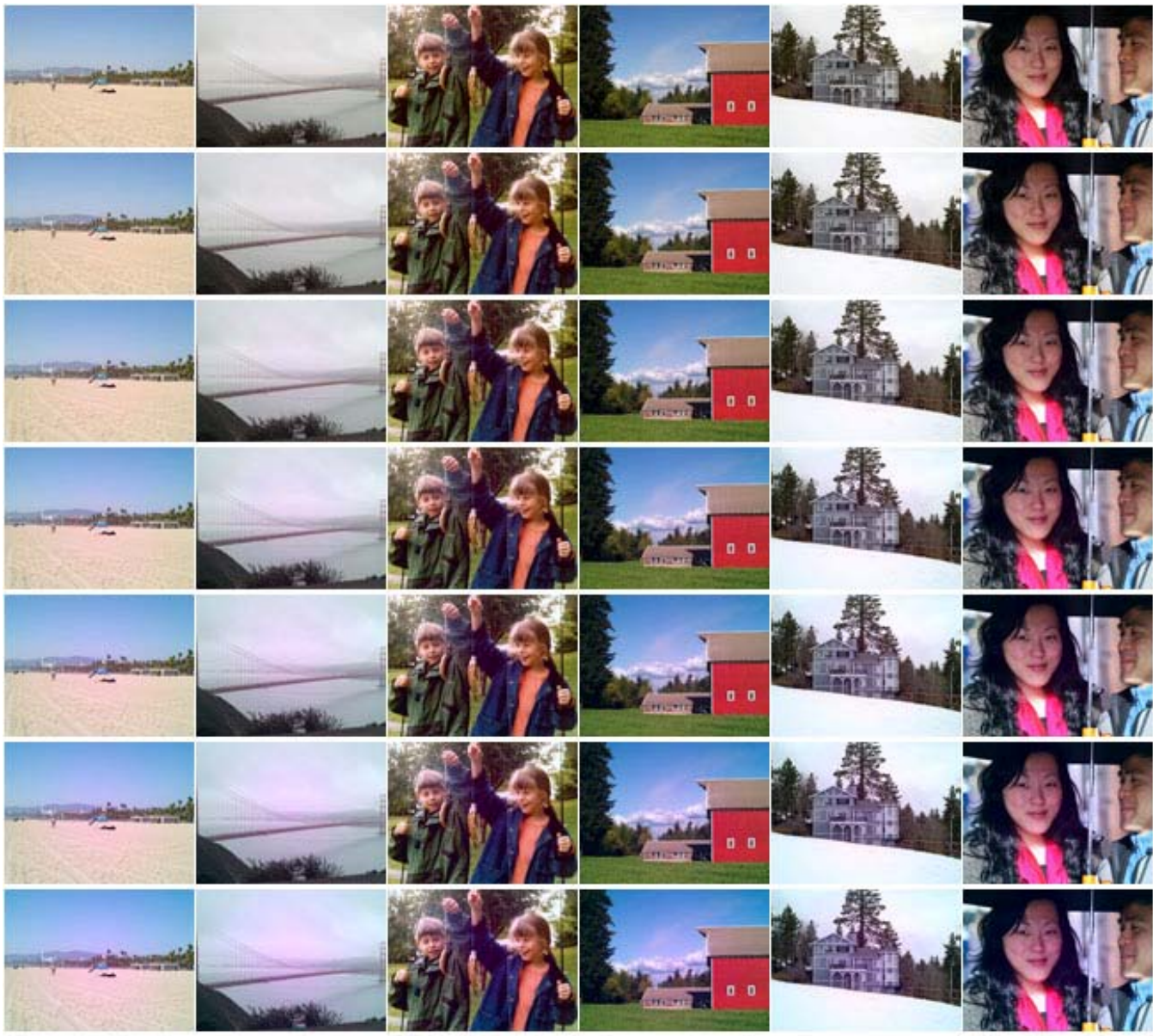
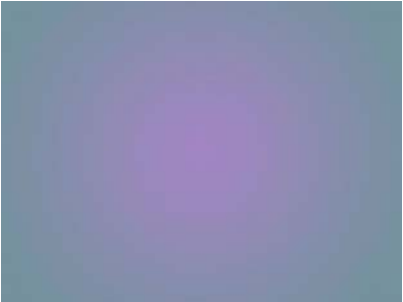
# Green Center



# Blue Center



# Purple Center

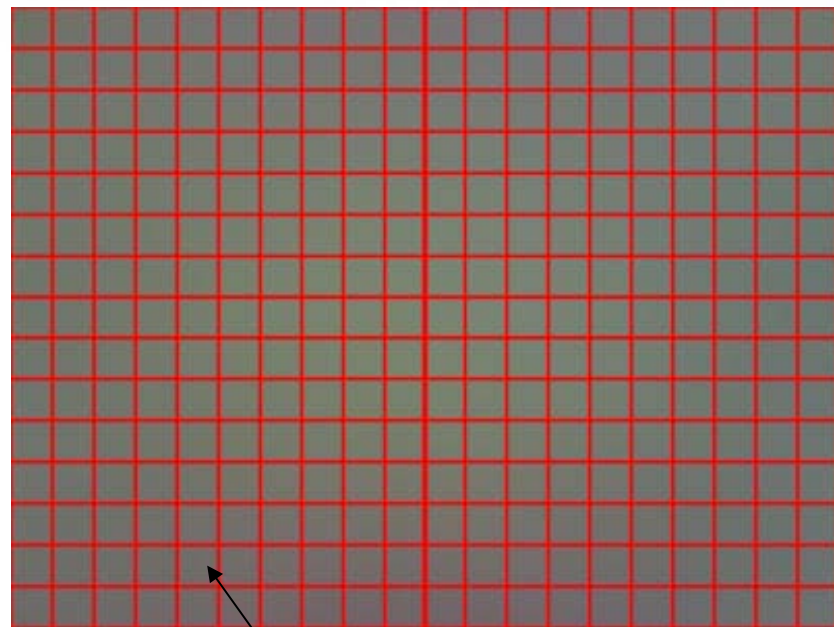


# Objective Metric Definition

- Divide image into grid ~ 20 x 15
- Compute average  $a^*$  and  $b^*$  per grid element
- Calculate overall average  $a^*$  and  $b^*$
- Determine maximum deviation of any grid element from average:

$$d_i = \sqrt{(a_i - a_o)^2 + (b_i - b_o)^2}$$

$$d = \max(d_i)$$



$a_i^*, b_i^*$

Grand  
Average

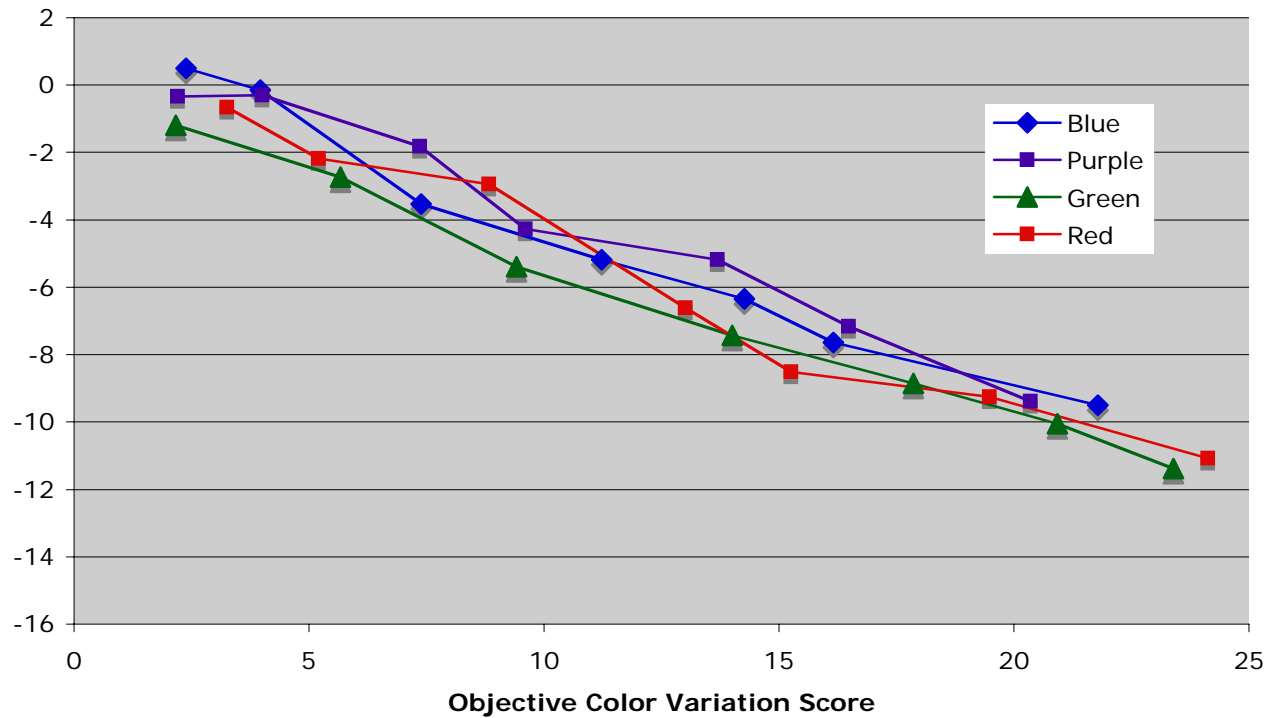
$a_o^*, b_o^*$

## Subjective Evaluation Results

- Softcopy ruler methodology used to characterize color non-uniformity in terms of JND loss from original
- Four independent test sites participated and data combined for overall metric characterization
  - Aptina Imaging, Hewlett Packard, Eastman Kodak, Vista Point
- Results presented using two approaches
  - Analysis of *average* performance across all scenes
  - Analysis for *worst-case* performance across all scenes

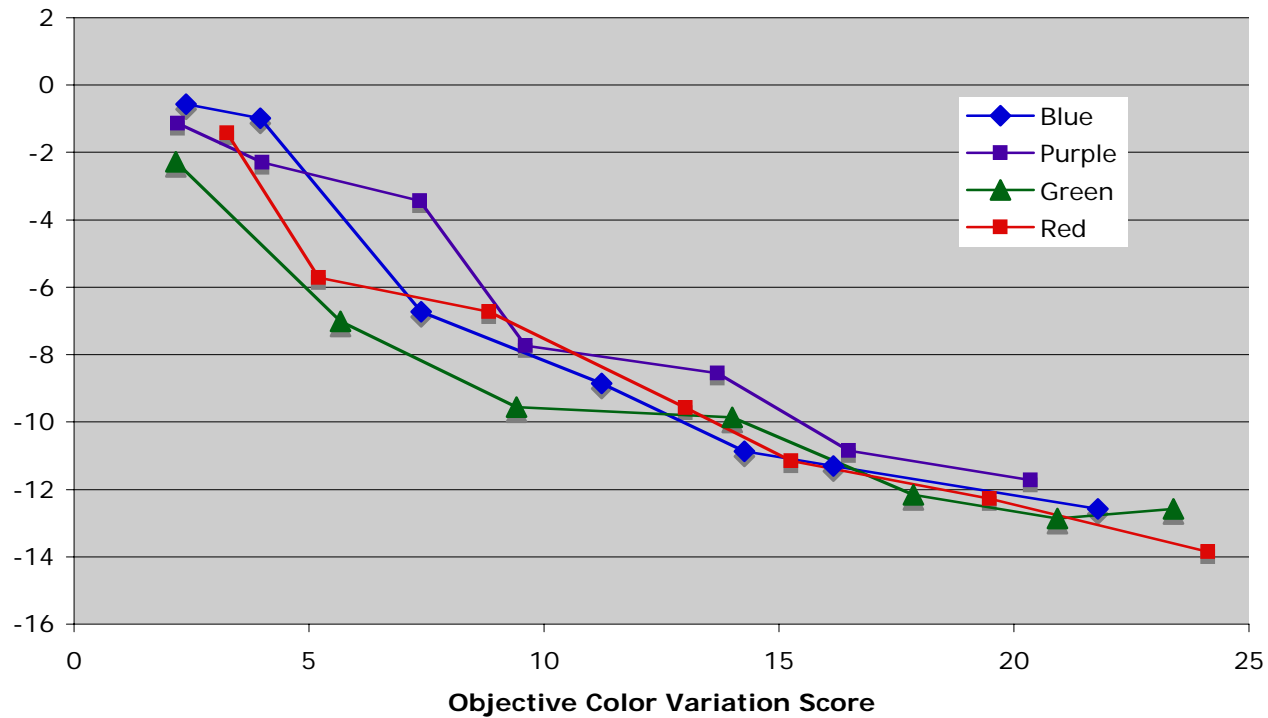
# Summary Performance Distribution

Softcopy JND Performance (Mean Level for all scenes)



# Summary Performance Distribution

Softcopy JND Performance (Worst-Case for all scenes)



# Application

- CPIQ document contains methods and procedures for implementing test and measurement methods
  - Apparatus, target, exposure conditions, etc.
  - Algorithm with example image data and sample results to confirm proper implementation
  - Subjective/Objective correlation plots
- Users can measure any camera-phone via this technique and quantify the visible magnitude of color non-uniformity
- Manufacturers and providers now have a method for establishing and validating specifications for allowable color non-uniformities

**Thanks for your attention!**

